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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior

*As revised and adopted at the Philadelphia meeting, January 1, 1941.

branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee.* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting

Section 9—*Quorum.* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SOCIETY AFFAIRS

RESUMÉ OF THE MEETING OF THE SOUTHERN SECTION

The fifth annual meeting of the Southern Section was held in conjunction with the convention of the Association of Southern Agricultural Workers in Atlanta on February 5, 6 and 7, 1941. The program carried 45 papers which were given in five sessions. Three symposia were held, namely, "The Southern Sweetpotato Research Program" with Dr. V. R. Boswell as chairman, "Research with Tomatoes in the South" with Mr. G. P. Hoffmann as chairman, and "Research with Peaches" with Dr. T. H. McHatton as chairman. A joint session was held with the Southern Division of the American Society of Agronomy on "Fertilizer Placement and Rapid Chemical Tests". All sessions were well attended.

The banquet and social evening was held at the Henry Grady Hotel with Dr. J. C. Miller as toastmaster. Dr. E. C. Auchter and Dr. T. H. McHatton, past presidents of the Society, gave short talks. The following officers were elected for 1941–42: Chairman—Dr. S. H. Yarnell, Vice-Chairman—Mr. W. S. Anderson, Secretary—Dr. J. B. Edmond. Members of the Executive Committee are Dr. H. H. Zimmerley (1942), Prof. G. H. Blackmon (1943) and Dr. W. S. Flory (1944).

RESUMÉ OF THE MEETING OF THE WESTERN SECTION

The Western Section of the Society held its meeting at the California Institute of Technology, Pasadena, California, in conjunction with the meeting of the Pacific Division of the American Association for Advancement of Science, on June 16, 17, 18, 19, 20, and 21, 1941.

A joint session with the American Society of Plant Physiologists dealt with Micronutrient Deficiency Diseases of Crops, under the chairmanship of Dr. D. R. Hoagland. At the horticulturists' dinner, Dr. W. H. Chandler was the principal speaker. A field excursion to the United States Regional Salinity Laboratory and a visit to the Citrus Experiment Station, concluded the program.

Officers in charge of the meeting were R. W. Hodgson, Chairman; A. H. Finch, Vice-Chairman; and W. W. Aldrich, Secretary-Treasurer.

The meeting for 1942 will be held at Salt Lake City, Utah, the third week in June.

L.D. Doneen, 1972

Some Factors Affecting the Rate of Growth of Pears

By A. H. HENDRICKSON and F. J. VEIHMEYER, *University of California, Davis, Calif.*

IN CONNECTION with experiments dealing with the irrigation of fruit trees, we have been measuring the circumferences of pear fruits during several seasons. The data were uniformly alike in that, when the circumferences were plotted against time the curves were essentially smooth, and the fruits from the irrigated and unirrigated plots grew alike until the permanent wilting percentage was reached in the unirrigated plot. From time to time, particularly when the measurements were taken at daily instead of weekly intervals, there were small departures from what might be called normal increases. When plotted as increases in volume, these departures were accentuated because of cubing the radii of the fruits measured. These departures were followed by compensating growth rates. In other words, if an unexpectedly high growth rate was found for a short period, it was followed by a low growth rate. The observed fluctuations in growth rate did not consistently follow the changes in evaporating conditions as measured by atmometers in the orchard, and further search was made for conditions of relatively short duration that were operative while the measurements were made. It was then found that, apparently, departures from the normal rate of increase coincided with the application of spray for the control of codling moth.

Recent work on various fruits attribute the rate of growth to such factors as soil-moisture conditions at or above the permanent wilting percentage, evaporating power of the air, changes in fruit-leaf ratio, temperature, and rain during the growing season. Aldrich and Work (1), working with pear trees on a clay adobe soil reported that "The rate of fruit growth (pears) was particularly sensitive to differences in available soil moisture", and that "Fruit growth was significantly decreased when the soil contained about 50 per cent of the maximum available moisture in the upper 3 feet". Hendrickson and Veihmeyer (2), however, working with pears on another clay adobe soil found no differences in rate of growth until the permanent wilting percentage was reached. In another paper Aldrich and Work (3) suggest that the evaporating power of the air influenced the rate of fruit enlargement. However, certain of their maximum and minimum growth rates occur under substantially equal evaporating conditions. Lewis, Work, and Aldrich (4) believed that the "rate of growth of pear fruit is markedly affected by comparatively small variations in the moisture content of the root zone, even when the moisture content is well above the wilting-point". They also reported the growth of pears was reduced when the soil moisture was reduced below 70 per cent of the available capacity, in contrast with Aldrich and Work who found a similar decrease in growth when the soil moisture was reduced to 50 per cent of the available capacity. Furr and Magness (5) reported that "in apple orchards trees can function at near the maximum rate so long as the moisture content of the whole root zone is appreciably above the wilting percentage", but a year later Furr and Degman (6) reported that the

"relative amount of available soil moisture had a measurable, though slight, influence on fruit growth — while the soil moisture was several per cent above the wilting percentage". Verner (7) presented evidence that atmospheric evaporation influenced the frequent changes in growth rate of apples, and that days of heavy rainfall usually coincided with rapid growth of the fruit.

Outline of Experiments

During the summer of 1940, studies were made of the rate of growth of pears with particular emphasis on the influence of spraying and artificially wetting the foliage of bearing trees. The circumference measurements were taken in the usual manner around the large part of the fruit and at right angles to the axis. Each fruit was marked with a spot of India ink at the place the measurements were taken. The measurements were taken with a steel tape attached to a homemade device which drew the tape around the fruit by the small spring inside the case. In this way the pressure exerted on each fruit was essentially the same for each series, and the measurement was not subjected to different pressures from day to day unconsciously exerted by the operator when measuring by simply drawing the tape around the fruit by hand. The measurements were taken on 25 fruits on each of four trees in each plot. In one case a single tree with 25 measured fruits was used for a special treatment.

One plot, with suitable guard trees, was left unirrigated during the period the fruit was on the tree, while the other was irrigated twice, the first time on June 6 and the second on July 16. A single tree near a convenient water hydrant in an irrigated plot was sprinkled several times by means of a lawn sprinkler attached near the top of the tree. The experimental trees in both the irrigated and unirrigated plots were sprayed with water by means of a barrel sprayer several times, and received two codling moth cover sprays. The trees were of the Bartlett variety, on Japanese pear rootstock, 23 years old but rather small for their age, possibly because of the severe pruning from time to time for the control of blight. The trees were growing in a Yolo loam soil having a moisture equivalent of approximately 22 per cent and a permanent wilting percentage of about 12.5 per cent. The fruits were measured at weekly intervals except when climatic conditions or special treatments warranted frequent measurements, when the fruit was measured daily. The measurements were taken between 8 a.m. and 9 a.m. Soil samples were taken at bi-weekly intervals.

Results of the Experiments

A continuous record of the growth of a pear fruit taken during the last week in June under conditions of clear warm weather and fairly uniform evaporating conditions is shown in Fig. 1. This record was obtained by using a modified hygrothermograph in which the hygrograph part was changed so that an extension rested on the fruit. The branch to which the fruit was attached was fastened firmly to a support built under the branches of the tree so that wind movement did not affect the position of the fruit. It will be noted that the fruit increased

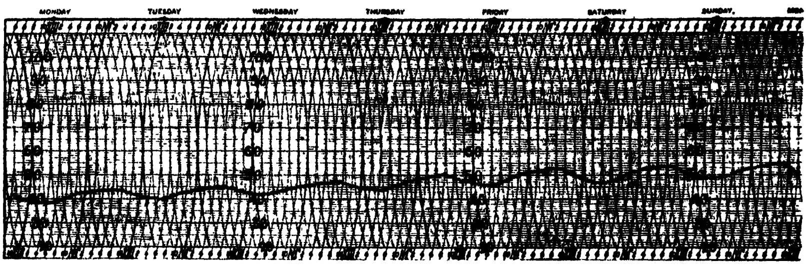

FIG. 1. Growth of Bartlett pear fruit obtained with a continuous growth recording device. The fruit increased in size during the night and decreased slightly during the day.

in size from about 6 p. m. until between 6 a.m. and 8 a.m. the following morning, after which it decreased. The measurements given in this paper were, therefore, taken soon after the fruits had reached the maximum size for the day. Sunrise occurred between 4:30 a.m. and 5 a.m. during the period most of the measurements were taken.

In order to find the magnitude of the variation that might be expected with the measuring device, 100 pears, 25 on each of four trees, were measured three times. These measurements were completed in about 75 minutes. The average circumferences thus obtained were 11.16, 11.16 and 11.15 centimeters.

The curves showing the volumes, assuming the fruits to be spherical, with respect to time are presented in Fig. 2, and showed substantial agreement with similar curves previously reported (2). It will be seen that in several places small irregularities occur, notably on June 8, June 20, June 28, July 12 and August 1. In addition, the unirrigated fruit began to grow more slowly than that from the other trees, shortly after June 22 when the soil moisture in the unirrigated plot was reduced to about the permanent wilting percentage. In general, the curves were concave upward with respect to time.

When plotted as rates of increase in cubic centimeters per day (Fig. 3), the variations previously shown in Fig. 2 are greatly accentuated. The fruits from all trees grew at approximately the same rate from May 24 to June 7. On June 8, there was a considerable decrease in rate of growth of the fruit from both the irrigated and unirrigated plots,

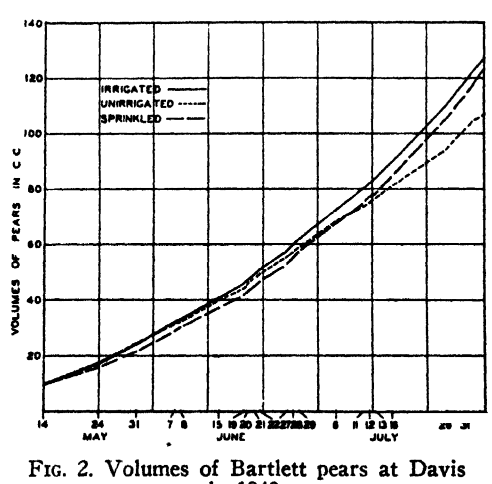

FIG. 2. Volumes of Bartlett pears at Davis in 1940.

while the fruit from the single tree, hereafter called the "sprinkled tree", for some unexplained reason increased in rate. The climatic conditions on June 7 and 8 were notable for high temperature, a dessicating north wind that blew day and night for several days, and the high evaporation rates, as measured by atmometers.

The next notable change in rates occurred on June 20. For a number of years we had noticed that similar increases in rate occurred from time to time, even when these changes could hardly be expected from the climatic conditions and that, furthermore, they could not be attributed to soil-moisture conditions as they occurred in both the irrigated and unirrigated plots. These changes were associated with the codling moth sprays. On the afternoon of June 19 the trees were sprayed with a cover spray for the control of this insect. The increase on June 20 was followed by a drop on June 22. Obviously, the recorded evaporation taken at some distance from the experimental trees did not represent the evaporating conditions at the leaf surface while the trees were being sprinkled. The rates decreased fairly uniformly between June 22 and June 27. This period had maximum temperatures ranging from 93 to 102 degrees F, although the evaporation from atmometers was moderate.

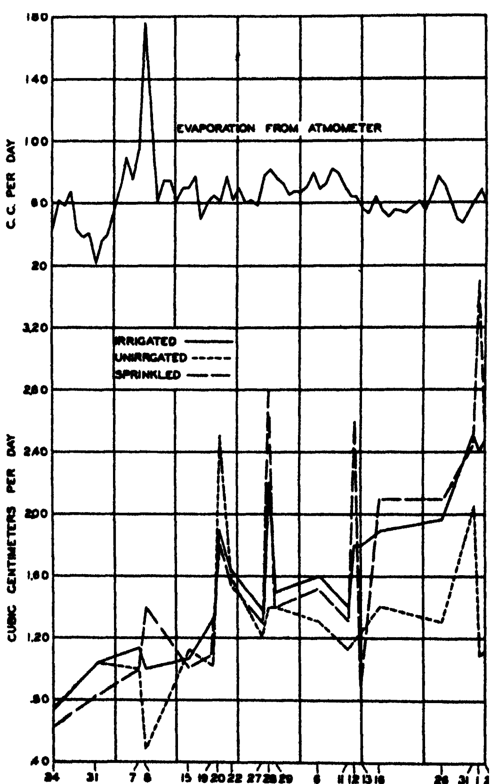

FIG. 3. Rate of growth of Bartlett pears at Davis in 1940.

The second pronounced increase in rates occurred on June 28, when the single, "sprinkled tree" and the trees in the irrigated plot were sprinkled with water. The amount of water that dripped from the tree did not wet the soil more than about ½ inch. The sprinkling of the trees in the irrigated plot was accomplished by repeatedly spraying the trees during the afternoon of June 27. The leaves were kept wet continuously from about 1 p.m. until 5 p.m. The increase in rate of growth of the fruit on June 28 and the decrease on June 29 are shown in Fig. 3.

The rate of growth of the pears in the unirrigated plot, although it increased and decreased in a manner similar to the

others, was substantially below that of the fruit from the irrigated plot and from the sprinkled tree after June 29. This effect may be attributed to the lack of readily available moisture in the top 4 feet of soil (Fig. 4).

No satisfactory explanation is available for the slight but uniform decrease in rates between July 6 and July 11. The maximum temperatures during this period were slightly lower than those during the previous period and the evaporating conditions were approximately the same.

The sprinkled tree was kept wet during the afternoon of July 11. The rate increased on July 12 but decreased the following day. All trees were sprayed for codling moth on the afternoon of July 26. In addition the unirrigated plot was sprinkled on the afternoon of July 30. The increase in rate of growth of the fruit in this plot as measured July 31 is rather remarkable when one considers that these trees were without readily available moisture in the top 4 feet of soil for over a month. The temporary effect of the sprinkling is indicated by the abrupt decrease in rate on August 1. The fruit from the irrigated plot increased in rate, as measured on July 31, although not so much as that on the other trees. Finally, the single experimental tree was sprinkled on the afternoon of July 31. The rate of growth was increased by the sprinkling, but decreased the following day.

The rate of growth of the fruit was not materially affected by the soil-moisture within the range between the field capacity and the permanent wilting percentage. The soil-moisture record is presented in Fig. 4. This record shows that the permanent wilting percentage was reached in the top 4 feet of soil in the unirrigated plot about June 29. The irrigated plot was watered on June 6 and on July 16. Both plots had readily available moisture throughout the season in the 5th and 6th foot depths. Apparently, the addition of water before the

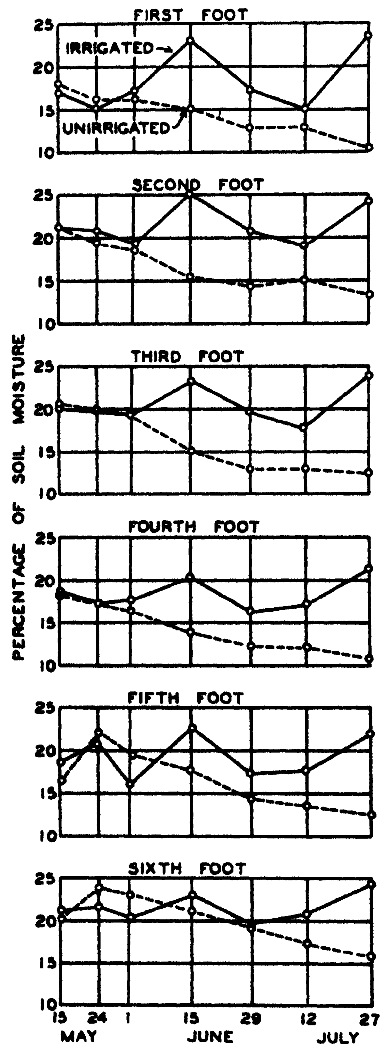

FIG. 4. Soil-moisture conditions in Bartlett pear orchard at Davis in 1940.

readily available supply was exhausted in the top 4 feet, did not influence the rate of growth of fruit in the irrigated plot (Fig. 2).

Discussion

The data presented show, in general, that the curves for the volumes of pears were substantially concave upward with respect to time, which means that the rates of growth in cubic centimeters per day increased during the season. The curves for the circumferences when plotted at weekly intervals were remarkably smooth, but when daily measurements were used small irregularities were apparent. When transferred to a volume basis, assuming the pears to be spherical, the irregularities were more pronounced, and when plotted as rates of increase, using daily instead of weekly measurements, they were greatly accentuated. The marked increases in rate were followed by decreases of approximately the same magnitude, indicating a temporary response to climatic conditions, that were produced at or near the surfaces of the leaves and fruit by the treatments given. The pear grower, of course, is chiefly interested in the final size of the fruit.

The data show that the rates of growth, when considered from the standpoint of approximately weekly measurements, were not changed decisively for more than a few days at a time, except by a reduction of the soil moisture to the permanent wilting percentage in the top 4 feet. Several investigators have reported on various factors, such as soil moisture and climatic conditions, and most of the data showed, but did not emphasize, the transient nature of these sudden increases and decreases. Our results indicate that, when readily available soil moisture is present, rates of growth of pear fruits quickly tend to return to former values following the sudden increase brought about by spraying or sprinkling the trees. These effects are particularly noticeable on June 29, on July 12, and on August 1 and 2. The effects obtained by the reduction of transpiration or possibly by absorption of moisture by artificially wetting the leaves was clearly shown even late in the season on the fruits on the trees in the unirrigated plot. Similar effects have been noticed in previous years following showers of rain. The common orchard operation of spraying for the control of insects or diseases may have been overlooked in the search for explanations of certain sudden but transitory changes in growth rates.

The data do not show whether the marked increases in rate of growth were due to increased turgor or increased growth. It would seem, however, that if the change were due to increased growth, the effect should be more permanent in nature, and the rate should not show such a marked decrease following each sudden increase.

Conclusions

The rate of growth of pears was reduced by the exhaustion of readily available moisture in the top 4 feet of soil. Irrigation before the readily available moisture in the top 4 feet of soil was exhausted had no effect on the rate of growth of pears. High temperatures and severe evaporating conditions seemed to reduce the rate of growth temporarily.

The artificial wetting of the leaves by spraying or sprinkling temporarily increased the rate of growth of the fruit, but the rate was reduced to approximately the previous level, the day following. Wetting the leaves increased the rate of growth of fruit temporarily even in the unirrigated plot where the trees had been without readily available moisture in the top 4 feet of soil for over a month.

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Influence of Sulphur Sprays on the Trunk Diameter of Young Apple Trees[1]

By E. P. CHRISTOPHER, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

THE influence of various sprays upon leaf efficiency (1, 4, 5) and of spray programs on tree growth and yield (2, 3, 6) has been the subject of recent researches. In most instances these studies have not involved new plantings as was the case in Maine (2), and therefore, it seemed worth while to start an experiment using common spray programs to determine to what extent growth, pest control, age of bearing, yield, and other factors are influenced under our climatic conditions.

PLAN OF EXPERIMENT

It was decided to use the McIntosh and Baldwin varieties for several reasons. First, they are the most important varieties in Southern New England; second, McIntosh is very susceptible to apple scab while Baldwin is much less so; and third, McIntosh is less susceptible to spray injury than is Baldwin.

The spray treatments selected include five in which liquid lime sulphur is used at least part of the time, flotation sulphur (Camden paste), sulphur dust and a check. The treatments follow:

1. Liquid lime sulphur 1–50 during the day.
2. Liquid lime sulphur 1–50 in early evening.
3. Liquid lime sulphur 1–100 during the day.
4. Liquid lime sulphur 1–50 through calyx followed by flotation sulphur 10 pounds to 100 gallons.
5. Liquid lime sulphur 1–50 through calyx followed by Kolofog 6 pounds to 100 gallons.
6. Flotation sulphur 10 pounds to 100 gallons.
7. Sulphur dust.
8. Check.

Arsenate of lead was added to all sprays using 3 pounds of arsenate of lead plus 6 pounds of high calcium spray lime and 40 per cent nicotine sulphate, 1 pint to 100 gallons, was used in two applications.

The soil used for the experiment is stony Narragansett loam on a gentle eastern slope and had previously been used for raspberry fertilizer experiments. It was heavily fertilized with hen manure and cover cropped with buckwheat and winter rye the year before initial planting. In the spring of 1936, an application of 1,000 pounds of a 5–10–5 mixed fertilizer was applied and spray plots laid out, running across the old plots. Trees were planted in 1936 and 1937. The cover crop of rye was turned under in early May, followed by cultivation until early July when buckwheat was sown to be followed by rye again about September 1. The hurricane of September 1938 did so much damage to the trees that they were not considered satisfactory for further growth records. Up to this time cover crops and tree growth seemed to indicate fairly uniform soil and fertilizer conditions.

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[1]Contribution No. 585 of the Rhode Island Agricultural Experiment Station.

In the spring of 1939, one-year whips 4 to 5 feet high secured from a large Maryland nursery were set out between the hurricane-damaged trees. The trees were set 20 feet between the rows and 10 feet apart in the row. Plots of five McIntosh and five Baldwin trees were laid out and replicated four times. No pruning has been given to the trees and the same fertilizer and cultural treatments have been continued. In 1939, spray treatments were not begun until June 6, which corresponded to the first cover spray. Four applications were made, two of which included lime sulphur for treatments 4 and 5. In 1940, five applications were made (two with lime sulphur and three with weaker fungicides for treatments 4 and 5), beginning May 27. In 1939, following the hurricane, there was almost no scab even on McIntosh. This condition was quite general, close to the coast. On the other hand, 1940 was a severe scab year and check trees showed considerable infection.

TABLE I—TRUNK DIAMETERS OF McINTOSH AND BALDWIN APPLE TREES AFTER TWO YEARS OF SEVERAL SPRAY PROGRAMS

Spray Treatment	McIntosh (Inches)	Baldwin (Inches)
Lime sulphur, 1–50, day	1.176	1.176
Lime sulphur, 1–50, evening	1.176	1.186
Lime sulphur, 1-100, day	1.278	1.368*
Lime sulphur, 1-50 (two applications) followed by flotation paste 10 pounds to 100 gallons	1.258	1.280
Lime sulphur, 1–50 (two applications) followed by Kolofog 6 pounds to 100 gallons	1.278	1.338
Flotation sulphur paste, 10 pounds to 100 gallons	1.290	1.318
Sulphur dust	1 336*	1.346*
Check—no fungicide	1.226	1.208
Needed for significances	0.120	0.168

*Significantly better than lime sulphur 1–50.

In Table I the data are presented on trunk diameters. Measurements were made in early November 1940, 1 foot above the ground level. The averages of the north and south and east and west diameters secured by caliper were used. On the basis of significance determined by analysis of variance, at the 5 per cent level of probability, only the dust treatment can be considered significantly superior to liquid lime sulphur 1–50 for McIntosh and dust and lime sulphur 1–100 for Baldwin. Folsom (2) found the effect of spray on growth to be cumulative and not pronounced in the first two or three years.

More detailed records on leaf size and injury are planned for next year. As soon as there is danger of crowding, every other tree in the rows will be removed and their weights obtained.

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Some Methods for Approximate Prediction of Surface Area of Apples

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ABSTRACT

This material will be published in full elsewhere.

THIS paper shows how the surface areas of apples may be obtained by using predicting equations involving various measurements such as, transverse diameter, axial diameter, area of axial cross section (through the stem and calyx ends), area of transverse cross section, and weight. By using the surface area of an ellipsoid with dimensions equal to the largest and smallest transverse diameter and the diameter of a "certain" cross section through the stem and calyx axis, very good results are obtained for the surface area of the apple; this formula, however, is difficult to use because it contains the elliptic integrals. Linear equations for predicting surface areas are shown to be about as accurate as the complicated ellipsoidal formula. Preliminary investigations indicate that a predicting equation based on weight of fruit may be the most accurate as well as the most practical one to use in predicting surface areas. In each case the standard error of estimate is obtained to show the accuracy of the prediction.

Some Correlations Between Growth and Yield of the Apple in Central Washington[1]

By E. L. Overholser, F. L. Overley, and J. C. Wilcox,[2]
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THE purpose of these studies was to determine some of the relationships between growth and fruiting of the apple, as found in the central apple growing region of the State of Washington. Attention has been concentrated on two specific phases of the subject: (a) the relationships between growth and yield when the records have been averaged for a number of years; and (b) the effects of annual variations in yield on tree growth or vigor. Separate consideration will be given in this report to the procedures and findings of these two divisions of the subject.

Review of Literature

Wilcox (7) has given a fairly complete review of the literature on the relationships between growth and fruiting of the apple. Mention may be made, however, of some of the more pertinent results reported since that time. Wilcox (7) found in 1937 that as the trees increased in size, the degree of vigor or rate of tree growth tended to decrease. In any one year, positive correlations were obtained between terminal length and increase in trunk circumference, and between terminal length and percentage bloom; but negative correlations were obtained between increase in trunk circumference and percentage bloom. This was shown to be related to biennial bearing. When factors other than biennial bearing were eliminated from the correlations, the correlations between terminal length and increase in trunk circumference in any one year became negative. Negative correlations were obtained between percentage bloom in any one year and the same the following year. Overholser, Overley, and Barnhill (3) in 1938 reported a significant increase in yield with an increase in size of tree. In 1939, Yeager and Latimer (10) reported highly significant correlations between girth and yield of apple trees. The same was reported by Wilcox (9) in 1940.

Source of Data

A number of fertilizer experiments have been conducted on apple trees in central Washington, and various records have been taken on these trees for a number of years. Some of the effects of plot treatments have already been reported (4, 6). The sources of data for these studies were the growth and yield records on (a) 69 Jonathan trees in the Tree Fruit Branch Station orchard at Wenatchee, (b) 45 Rome trees

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in the same orchard, and (c) 27 Winesap trees in the Enslow orchard at Manson. In making the correlations reported, no attention has been paid to the effects of plot treatments. The specific records used will be noted as occasion requires. The procedures used in recording the various measurements have already been outlined (5). The data obtained from 1935 to 1938 inclusive were utilized, because more complete records were available for this period of time on these three series of plots.

A. Relationships Between Growth and Yield With Records Averaged for a Four-Year Period

The records used for this study were as follows: Trunk circumference in centimeters (C); Cross-sectional area of trunk in square centimeters (A); Increase in trunk circumference in centimeters (I); Terminal length in inches (L); Growth index ($G = I \times L$).; and Weight of fruit produced in pounds (W). The letters in brackets are the symbols used to represent these measurements. The use of the growth index as a measure of tree vigor was first suggested by one of the authors in 1937 (8). It was considered desirable to determine whether any benefit would accrue from its use in these correlations. On each tree, the data for each type of measurement were averaged for the four-year period, 1935 to 1938. This period was considered sufficiently long to eliminate in large measure the effects of seasonal variations on the averages. It was also planned to correlate the biennial bearing tendencies with growth and yields, but as there was little tendency toward consistent biennial bearing found in any of the three varieties, these correlations were not made.

The correlations made and the coefficients obtained are indicated in Table I. Partial correlations were also calculated, but they added little information of value. On the basis of the results presented, conclusions may be drawn as follows:

(a) There was very little difference between the A-W and the C-W correlations, which would indicate that for these trees the trunk circumference and the cross-sectional area of the trunk should be equally

TABLE I—Correlations Between Growth and Yield, With Records Averaged for a Four-Year Period

Two Measurements Correlated	Coefficients of Correlation		
	Jonathan	Rome	Winesap
C-W†	0.529**	0.450**	0.161
A-W	0.534**	0.536**	0.146
A-L	0.215	0.148	0.284
A-I	0.391**	0.486**	0.345
A-G	0.357**	0.440**	0.352
L-W	0.512**	0.229	0.325
I-W	0.526**	0.229	0.511**
G-W	0.554**	0.239	0.579**
I-L	0.705**	0.508**	0.544**

†Meaning of letters used follows: A, Cross sectional area of trunk; C, trunk circumference; G, growth index (I ×L); I, increase in trunk circumference; L, terminal length; W, weight of fruit produced.

**Coefficients highly significant, with odds greater than 99:1.

Other figures are non-significant, with odds less than 19:1.

satisfactory as measures of the bearing area of the tree. The distribution charts showed considerable deviation away from the line of trend in every case, apparently resulting in large part from the effects of plot treatment. On this account, no attempt was made to use the geometric mean between C and A, as was done by Wilcox (7) in British Columbia.

(b) There were highly significant positive correlations between A and I and between A and G with the Jonathan and Rome. Although the other correlations between size of tree and rate of growth were not significant, they showed a definite tendency toward a positive correlation. In other words, the larger trees tended to be more vigorous than the smaller trees. This agrees with the findings of Overholser, *et al.* (3) but is in marked contrast to the findings of other investigators (1, 2, 7, 9). The reason is to be found in the fact that fertilizer treatments had been applied to these trees for some years before the records were taken, so that the nitrogen applications had produced not only the most vigorous trees but also the largest trees. It is interesting to note that the largest trees in an orchard do not necessarily have to be the least vigorous ones.

(c) The L-W, I-W, and G-W correlations were all highly significant in the case of the Jonathan. In other words, the greater the vigor, or rate of growth, the greater the yield. This same tendency was quite marked also with the Winesap, but not so much so with the Rome.

(d) Of the three measurements of vigor used (L, I, and G), I and G showed distinctly higher correlations with A than did L. In addition, the I-W and G-W coefficients were in general higher than the L-W coefficients. For these trees, then, either I or G would appear to be preferable to L as a measure of tree vigor over a period of years. There would seem to be very little if anything gained, however, by determining G for use in addition to or in place of I. These findings do not of course necessarily apply to other districts, varieties, or treatments (6).

B. Some Effects of Annual Variations in Yield on Vigor or Tree Growth

The records used for this study were those from the Jonathan trees growing in plots of the Tree Fruit Branch Experiment Station as follows: Number of fruits per tree (N); Weight of fruit per tree (W); Increase in trunk circumference (I); and Terminal length (L).

As previously noted, very little tendency was found toward systematic biennial bearing by these trees over a period of years. There remained the possibility, however, that the size of crop one year might affect the formation of fruit buds and hence the size of crop the following year. In order to determine this, the number of fruits per tree in 1935 was correlated with the number in 1936. This was also done for 1936 and 1937, and for 1937 and 1938. The results are presented in Table II. The 1935–1936 and 1937–1938 correlations were both negative and highly significant, while that for 1936–1937 was negative and significant. The reason for the lower correlation in 1936–1937 was that in 1937 almost every tree bore heavily, even those that had borne heavily the year before. Aside from this exception, there was during

the four years a distinct tendency for a comparatively heavy crop to be followed by a comparatively light crop, and vice versa. Over a period of several years, however, there were few trees that could be considered really consistently biennial bearers. In other words, the off-and-on-year sequence seldom lasted for more than two or three years at any one time.

As pointed out by Wilcox (7), the alternate year correlations between growth and yield cannot be satisfactorily determined without eliminating the effects of factors other than biennial bearing. This was accomplished here by the ratio method. The terminal lengths for 1935 were divided by those for 1936, and the same was done for 1937 and 1938. The ratios thus obtained were considered as one distribution and were labeled L1/L2. The same procedure applied to I and to W gave the ratios I1/I2 and W1/W2. Owing to the lack of some of the data for I, the number of trees whose records could be used was much less than with L and W. The results of the correlations among these three ratios are outlined in Table II. On the basis of the data presented, conclusions may be drawn as follows:

TABLE II—Some Correlations Between Growth and Yield in Alternate Years

Two Measurements Correlated	No of Trees	Coefficient of Correlation
N1935–N1936†	57	–0 392**
N1936–N1937	57	–0 282*
N1937–N1938	57	–0.416**
L1/L2–W1/W2	114	0 341**
I1/I2–W1/W2	79	–0.224*
L1/L2–I1/I2	79	0.014

†The meaning of letters used follows: I, increase in trunk circumference; L, terminal length; N, number of fruits per tree; W, weight of fruit per tree.
**Coefficients highly significant, with odds greater than 99:1.
*Coefficients significant, with odds between 19:1 and 99:1.
Last correlation non-significant.

(a) There was a strong tendency for a comparatively heavy crop to be followed by a comparatively light crop, and vice-versa.

(b) There was a highly significant positive correlation between L1/L2 and W1/W2. In other words, the terminals tended to be longer in the "on" year than in the "off" year.

(c) The correlation between I1/I2 and W1/W2 was significant and negative. That is, the increase in trunk circumference tended to be smaller in the "on" year than in the "off" year.

(d) There was no evidence of any relationship between terminal length and increase in trunk circumference. The reason for this lack of correlation has not been determined. The correlations between L1/L2 and W1/W2, and between I1/I2 and W1/W2, would lead to anticipation of a negative correlation between L1/L2 and W1/W2.

The authors wish to express their appreciation to R. M. Bullock and R. S. Carrasca, graduate students in Horticulture at the State College of Washington, for assistance in making the statistical calculations required for this report.

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Infiltration Rates in a Yolo Loam Soil as Affected by Organic Matter

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THOSE concerned with irrigation agriculture find rates of water penetration into a soil important both from soil moisture supply and salt leaching points of view. The infiltration rate, the rate at which soil takes water when free water is standing on the surface, is a good index of ability to economically and satisfactorily irrigate a soil.

Duley and Kelly (1, 2) have demonstrated that the condition of the soil surface is the principal factor affecting infiltration rates into a uniform soil, frequently more important than the soil type itself. This has been demonstrated (3) as regards detrimental effects of some commercial fertilizers, and appears to result from mechanical redistribution of the particles with downward movement of the water when aggregates are not water-stable. That organic matter and the accompanying activity of micro-organisms increases the infiltration rate capacity has been amply demonstrated by many investigators such as Free, Browning, and Musgrave (4), by Martin and Waksman (5), as well as by earlier investigators listed by (1, 2, 4, 5), and by the writers (3).

From 32 field basins 3 feet by 3 feet with vertical wood sides in Yolo loam soil at Los Angeles, we have obtained some preliminary data on the effect of organic matter which are in agreement with the above references, but are more directly indicative of conditions under irrigation. At each irrigation 5¼ inches depth of Los Angeles city water was applied through a carefully calibrated meter. The data presented represent the average rates of infiltration, timing commencing when water was first applied and ending when the soil surface was half bare of water. A screen and sack arrangement was used to prevent the water applied from disturbing the soil surface. Four irrigations were applied before differential treatments were attempted. Each treatment was replicated four times. A barley cover crop was planted on November 11 in 16 basins (four treatments), all 32 basins being similarly cultivated and treated (except for the seed) at that time. All basins were hand weeded bi-weekly, except for the barley cover cropped basins while the plants were growing. The barley plants were cut off at the ground surface on January 28, and nothing was allowed to grow on any basin subsequently. Immediately before the irrigation of January 28, heavy rains had brought the moisture of all basins up to at least field capacity at all depths. At other times the soil surface appeared dry prior to irrigation. Before the irrigation of March 11, practically all visible organic matter had disappeared from the surface of all basins.

The differential treatments employed follow:

1. Same as No. 2 to date.
2. Bare, used as "check" treatment, no cultivation after differential treatments started.

3. Same as No. 2, except cultivated March 25.
4. 4-inch corn stalk mulch placed on surface November 11.
5. Barley grown, tops left on surface when cut.
6. Barley grown, tops removed when cut.
7. Barley grown, tops left on surface when cut, cultivated March 25.
8. Barley grown, tops removed when cut, cultivated March 25.

Data on infiltration rates are given in Table I. In order to better compare the various treatments with the check, No. 2, Fig. 1 has been

TABLE I—AVERAGE INFILTRATION RATES FOR PRE-TREATMENT IRRIGATIONS AND FOR SUBSEQUENT INDIVIDUAL IRRIGATIONS

Treatment No.	Average Rate (Inches Per Hour)					
	Pre-Treatment Average	Irrigation of Nov 26, 1940	Irrigation of Jan 28, 1941	Irrigation of Mar 11, 1941	Irrigation of Mar 27, 1941	Irrigation of May 13, 1941
1	6.54	5.09	3.97	1.80	0.72	1.08
2	7.02	5.73	4.42	2.02	0.88	1.41
3	6 74	5.19	3.12	2.07	1.85	1.09
4	6.50	6.03	8.46	9.18	6.06	5.25
5	6.51	5.63	7.22	7.47	4.90	6.68
6	7.50	5 76	8.17	5.65	3.65	4.40
7	6.67	4.66	7.76	7.67	4.32	1.94
8	6.41	5.24	8.42	3.86	3.49	1.34

prepared. In this, the rate for treatment No. 2 is given an arbitrary value of 100. Account is taken of the pre-treatment average infiltration rates and the variations existing from irrigation to irrigation. A direct comparison is therefore made of each treatment with No. 2.

The consistent records of the pre-treatment rates for all basins

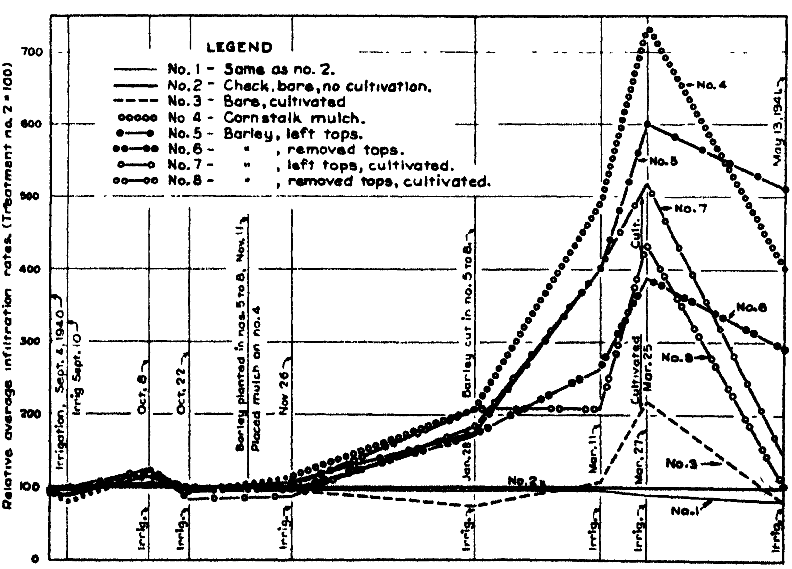

FIG. 1. Relative infiltration rates for each treatment (4 basins) at each irrigation.

demonstrate the reliability of the results for differential treatments. Treatment No. 1, which to date has been the same as No. 2, shows a close correlation with the latter. Results for treatment No. 4 demonstrate the value of organic matter, but cannot be directly compared with the cover crop treatments. Treatment No. 3 shows an increase in infiltration rate for only one irrigation following cultivation, indicating that the effect of cultivation was extremely temporary in nature.

With the cover crop treatments, greatest effect was not noted until the tops had been cut and decay had started. Treatments Nos. 5 and 7 demonstrate the more permeable condition resulting when the cut tops of the cover crop are left on the ground surface. Treatments Nos. 6 and 8 show that much of such benefit is lost if the tops are removed. Treatments Nos. 7 and 8 show appreciable loss in infiltration capacity following cultivation. (That cultivation turned under soil with a structure favorable to infiltration and brought soil with less favorable structure to the surface.)

The beneficial effects of organic matter on infiltration rates are thus demonstrated, as is the temporary nature of cultivation under these conditions. The principal effect of a cover crop was not noted until after it had been cut and decomposition had started. Rates were appreciably greater when the cut tops were not removed. Increased infiltration rates associated with applications of organic matter appear to result mainly from the influence the organic matter has upon the surface soil.

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Further Studies of the Value of Trunk Measurements in Interpreting Apple Tree Growth[1]

By R. D. ANTHONY, *Pennsylvania State College, State College, Pa.*

IN THE spring of 1927 an orchard was started at State College in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture to study the performance of Stayman apple trees on various understocks. The trees were planted 20 feet by 20 feet in units of three rows, each row containing 29 trees. Space for a single row was left between each two units to be planted later to Starking or Golden Delicious to aid in pollination and to assist in estimating soil variability. Stayman trees for the first unit were purchased from a commercial nursery company and were on French crab seedling roots. A fourth row was planted with trees from this same source to give an outside, guard row. The second unit of three rows was composed of Stayman trees on a clone root, USDA T200. The third unit was Grimes on this same clone. This also was planted to aid pollination.

In the spring of 1929, the following units, each of three rows, were added: Stayman on Malling XII, on Malling XIII and on Malling XV. These stocks had been secured directly from East Malling, England, and were budded by Mr. G. E. Yerkes with buds from a Stayman tree in one of the experiment orchards at State College. The trees were one-year-old when planted as were those put out in 1927.

In the spring of 1930 the single rows between the units were planted with Malling I stocks, again secured directly from England. Two weeks later these were stem-grafted 4 to 6 inches above the ground with scions of Starking and Golden Delicious secured from the Stark Nurseries.

At the time this orchard was started at State College in 1927 a somewhat similar planting was made at Morgantown, West Virginia, to study the performance of Winesap and Delicious on French crab seedlings and on T200 roots. A report of the first 11 years of this planting was made before this Society in 1937 (1). The origin of the clone, T200, is discussed in that report. Also in that report is given the performance, through 1937, of the first two units of the orchard at State College — trees on French crab seedlings and T200 roots. It was concluded that at State College the T200 roots induced more variability in growth and yield than the seedlings, whereas at Morgantown, Delicious and Winesap were more uniform on the clone roots than on the seedling roots. As will be seen later in this paper, there were definite reasons for the greater variability of the trees on T200 at State College.

Before discussing growth correlations in these plantings, something should be said about the variability within the different units. In the State College orchard of approximately 8 acres, six different cultural treatments were established at right angles to the understock units.

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One of these was nitrated bluegrass which was lightly broken nearly every year. The rate of response to these different treatments has not been the same by the trees on the different stocks. T200 roots have seriously dwarfed the Stayman trees and the growth of these dwarf trees has been checked much more by the bluegrass sod than has been the case with more vigorous trees. Another major cause of variation in this block will be discussed later. Grimes on this same clone, T200, has been dwarfed but little by it and these trees have not been checked to any considerable extent by the bluegrass sod. There are indications that the trees on Malling I also have been checked somewhat by the grass treatment.

In the 1927 planting at State College, the commercial trees on French crab seedlings had been carefully selected from a nursery planting of several thousand whereas there was little opportunity to select the clone roots for uniformity because of the small number of trees available in the Arlington nursery (2). With the trees on seedling roots the coefficients of variability for weight of tree and for trunk diameter at planting were 17 ± .76 and 7 ± .03, respectively, while with the Stayman trees on clone roots these coefficients were 30 ± .15 and 10 ± .04. The correlations of trunk diameter to weight of tree at planting was .75 ± .02 for Stayman on French crab and .77 ± .02 on T200 (3). After 11 years' growth the records in both the Morgantown and State College orchards show no pronounced correlation with size of tree at planting (1).

By 1935 the Stayman trees on French crab roots at State College which were standing 20 feet by 20 feet were crowding seriously. Late that fall every other tree was pulled out with a tractor, the roots cut off at the ground line and the trunk and branches weighed. The roots were not weighed as the proportion of roots left in the ground was quite variable. Fifty-eight trees were removed. With these trees the coefficient of variability with respect to weight of tops was 22 ± .12 per cent; with respect to trunk circumference it was 9 ± .12 per cent. The coefficient of correlation of weight of top and trunk circumference was .63 ± .05. In a previous study (2) it was found that using the square of the circumference in similar correlations increased the value of the coefficient. In this report trunk measurements have not been squared.

In the fall of 1937, alternate trees were removed in the Morgantown orchard. Here the correlation of trunk circumference with weight of top was .89 ± .03 with Winesap and .91 ± .03 with Delicious (1).

By the fall of 1939 the increasing size of the trees throughout the orchard at State College made it necessary to pull out every other row across the stock units. In all, 277 trees were removed. Again the trunks were cut off at the ground line and the tops weighed. The circumference of all trees was measured before any were removed. Table I gives the major computations from these measurements. Before analyzing this table, a further cause for variability in the unit of Stayman trees on T200 should be noted. During the early years these trees were quite uniformly dwarfed except where the bluegrass had further checked them. Later certain trees had begun to make a more nearly normal

TABLE I—RECORD OF TREES REMOVED AT STATE COLLEGE (FALL 1939)

Stock	Scion	No.	Ave Trunk Circumference (In)	C Trunk Circumference	Ave Wt Tops (Lbs)	C Weight Tops	r Circumference to Weight
			Planted 1927				
French crab	Stayman	25	24±.33	10± .9	342±11	24±2.4	.83±.04
T200	Stayman	39	16±.35	20±1.5	145± 8	55±5.3	.98±.003
T200	Grimes	36	20±.23	10±1.1	211± 5	24±2.0	.90±.02
			Planted 1929				
M XII	Stayman	39	20±.17	7± .5	270± 7	27±2.2	.84±.03
M XIII	Stayman	38	18±.23	11± .9	209± 7	31±2.4	.94±.01
M XV	Stayman	38	16±.20	10± .8	157± 4	23±1.8	.81±.03
			Planted 1930				
M I	Starking	36	12±.21	14±1.0	87± 4	10±0.8	.84±.07
M I	Golden Delicious	26	14±.23	12±1.1	70± 7	28±2.7	.91±.03

growth and it was suspected that these trees had formed scion roots. When alternate rows in this block were pulled out, this was found to be the case.

From the descriptions given it is evident that there are several causes for plot variability and this shows in the coefficients of variability in Table I. Nevertheless, compared to the usual commercial orchard, these units are much more uniform. It is possible that this is a factor in the high correlation of circumference and top weight, but the fact that one of the most variable units — Stayman on T200 — has the highest correlation would rule against this.

In giving proper weight to these high correlations it must be remembered that they were secured with young trees just coming into good production. Also these trees have been under a uniform pruning system which has removed relatively little wood.

The records of two other groups of Stayman trees grown at State College under quite different conditions are of interest. In 1921 and 1922, 42 Stayman trees budded on Malling XII roots were planted in uniform soil in large metal cylinders. These trees were grown under various fertilizer treatments until the fall of 1927 when they were carefully dug out, the tops cut off at the ground line and tops and roots weighed (4). Each year, during the life of these trees, the entire branch growth made by each tree had been measured. Also all prunings had been weighed for each tree. In 1928, these 42 cylinders were again filled with uniform soil and planted to Stayman trees on Malling XII

TABLE II—CORRELATION OF TRUNK MEASUREMENTS WITH TREE GROWTH IN 42 STAYMAN TREES ON A CLONE ROOT GROWN IN METAL CYLINDERS

Records Correlated	Coefficient of Correlation	
	First Group 1921–27	Second Group 1928–38
Trunk measurement* to total top weight	.88±.02	.92±.01
Trunk measurement* to total branch growth	.83±.03	.91±.01
Trunk measurement* to total tree weight†	.87±.02	.72±.05

*Diameter of trunk used for first group; circumference for second.
†Includes tops, roots and all prunings.

roots and a second series of cultural treatments established. In the fall of 1938, these trees were dug out in the same manner as the first group. Table II gives the correlations of the trunk measurements in these two groups with top weight, branch growth and total tree weight.

The restriction of the roots by the metal cylinders brought these trees into fruiting earlier than with similar trees under field conditions. Therefore these trees are older, physiologically, than those in the orchards. In spite of this and many other unusual conditions under which these trees grew, the correlations are high.

These high correlations with six varieties grown under a considerable range of conditions would seem to indicate the advisability of using trunk measurements as one of the chief indexes to tree growth during the early years of the apple orchard. No study has been made of yield correlations in these young trees. Waring's early report of the relation of circumference to yield (5) in a considerable range of bearing commercial orchards and a later report covering 25-year-old trees at State College (3) gave lower correlations than those reported above for circumference and tree growth, but in most blocks the value was high enough to be of considerable significance. Yeager and Latimer, reporting last year (6), also found girth and subsequent yield significantly correlated.

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Response of Devitalized Apple Trees in Quackgrass Sod to Ammonium Sulphate (Preliminary Report)

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THIS work was initiated to study the time and rate of movement of nitrogen from a readily available nitrogenous fertilizer to the aboveground tissues of apple trees. For the study it was desired to employ trees which were uniformly low in vigor. This condition was best found in trees growing in quackgrass sod. In addition, the presence of quackgrass afforded an opportunity to observe the effect of the sod on utilization of nitrogen by apple trees.

Nineteen-year-old Delicious apple trees, extremely low in vigor and growing in heavy quackgrass, received 3, 6, 15, and 25 pounds of ammonium sulphate per tree. The fertilizer was applied broadcast under the spread of the branches and carried into the soil by rain and irrigation water. Time of application was March 4, 1940, 46 days before full bloom.

Twelve days following full bloom the sod under trees treated with 6, 15, and 25 pounds of ammonium sulphate was making rapid growth and was very dark green. The demarcation between fertilized and unfertilized areas was very striking. The trees, on the other hand, showed no response until 32 days after full bloom. At this time leaves on trees receiving 15 and 25 pounds of ammonium sulphate per tree became darker green in color, but none of the other trees in the experiment showed any response to the applied nitrogen during the entire growing season.

Analyses of leaf samples taken at frequent intervals throughout the season indicated that spring applications of ammonium sulphate, in the amounts employed, increased the total nitrogen content of the leaves only slightly. Chlorophyll content of leaves from trees receiving 15 and 25 pounds of ammonium sulphate, however, increased almost threefold. This indicates that an increase in chlorophyll content of nitrogen deficient trees is not a clear indication of how much nitrogen may have been taken up by the tree or how much nitrogen was deposited in the leaves.

Quackgrass was found to be a heavy consumer of nitrogen. In an area of 624 square feet, receiving 25 pounds of ammonium sulphate, the plants including roots and rhizomes increased in nitrogen over the unfertilized an amount equivalent to 13.3 pounds of ammonium sulphate. This was in agreement with the observation that no measurable response to fertilizer applications was obtained in trees treated with less than 15 pounds of sulphate per tree.

Analysis of the soil in early November indicated that the ammonium sulphate, even at the rate of 25 pounds per tree, did not move appreciably below the first foot of soil. The concentration of SO_4 in the upper foot of soil increased in proportion to the amount of fertilizer added. The NH_4, on the other hand, had practically all disappeared except for a small amount remaining in the 25-pound treatment.

Analyses of bark, twigs, and roots, sampled after the growing season, showed that none of the nitrogen applied was stored in the aboveground portions of the tree. The roots from the 15-pound treatment evidenced some increase in nitrogen, while those from the 25-pound treatment showed a decided increase, but, due to the variability inherent in root sampling, the actual amount of nitrogen taken up could not be determined accurately.

The evidence indicates that in the first season after treatment part of the fertilizer, in excess of quackgrass and soil organism utilization, was taken up by the apple roots and held as reserve nitrogen, except for a very small quantity which was transported to the leaves. This small quantity, however, increased the chlorophyll content threefold. These conclusions are in accordance with the concept suggested by Magness (1) that the performance of an apple tree, in a particular season, depends primarily on nitrogen reserves already stored in the tree, rather than on the nitrogen applied the same spring or summer.

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Temperature Differences Within an Orchard and Their Effects on the Fruit[1]

By WILLIAM S. CLARKE, JR., *Pennsylvania State College, State College, Penn.*

AFTER the very severe winter of 1935–36, a survey was made to determine the extent of winter injury to fruit trees in Pennsylvania and adjoining states (1). While a considerable amount of injury was discovered, it was quite variable, being very severe in some orchards and much less severe in other orchards not far away. In many cases cultural and other practices of the fruit grower contributed to the injury, but in some cases there were evidently local weather variations affecting the amount of injury. The question arose as to the temperatures reached in the different orchards at critical times, and on this point there was very little available information. In the few cases where thermometers were kept in orchards, they were at the farm buildings, which are usually not representative of orchard conditions. Most records of low temperatures were those of weather stations located in county seats or other nearby towns.

It has long been recognized that considerable differences may exist between temperatures in towns, where most weather stations are located, and in open country. On a number of occasions serious frost damage has occurred in the college orchards when temperatures recorded in the nearby town of State College indicated that no damage should occur. The data presented by Chandler (2) and by others have shown that considerable differences in temperature may occur within different points in one orchard area and that these differences may affect the frost damage to the trees. However, the actual differences in temperature have not often been stated. This study was made in an attempt to answer the questions as to the differences in temperature between the town and adjacent orchard land and as to the differences within the orchards themselves and of their correlation with frost and other cold weather damage throughout the orchards.

At State College there is an official co-operating weather station. It is situated on the summit of a slight ridge, with good exposure to the north and north-west winds usually prevailing during periods of cold weather. To the north-west is an open area which includes the college flower gardens. About 30 feet to the east is one of the college buildings, and about 100 feet to the south-west is another college building. The land is again open for some distance toward the south and south-east, sloping downward from the weather station. State College itself is situated in the middle of a broad valley 10 miles wide bordered by steep mountain slopes which rise 1,000 feet or more above the valley floor. Within this valley are smaller changes in elevation as streams have eroded minor valleys throughout it. The college weather station is situated on one of the higher points in this valley.

The college orchards are situated due north about 1½ to 2½ miles

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away, on an extension of this ridge, but at an elevation from 50 to 100 feet lower. They extend over an area about 1 mile at the largest diameter and are on fairly level to slightly rolling land. In most places the land slopes away from the orchard, at times gently, and at other times steeply. A half mile to the north of the orchard land is a narrow valley with an elevation 100 feet lower than most of our orchard land; and to the south-east of the farther orchard the land drops sharply to a creek bottom and valley 200 feet lower than the highest point in the orchard.

Our farm buildings are adjacent to the orchard nearest the college weather station. On the lawn to the north and about 30 feet from the house near these buildings was placed a standard weather instrument shelter. The position of this shelter is indicated on the chart by a cross within a circle. It lies at an elevation 100 feet lower than the college weather station. To the north and west of this shelter are 200 feet of garden and nursery land; then the land slopes rather steeply toward an arm of a valley which, a half mile away, has an altitude 100 feet lower. Immediately beside the shelter, to the east, is a grape vineyard of about half an acre. Farther to the east and to the south, across a road 200 feet away, is a fairly level stretch of orchard land. In this shelter records of maximum and minimum temperatures have been kept daily for more than 3 years, and these records have been compared with those of the college station.

In 32 months of records the average daily minimum temperature at the orchard was only 0.74 degrees F lower than that at the college weather station. However, large daily deviations often occurred. On cloudy or windy nights the temperatures at the orchard were often higher than those at the college station; but on clear, still nights the temperatures were often much lower. Deviations of 5 to 8 degrees were common, and a few deviations of 10 degrees were noted. In still, clear nights during the critical periods in the spring and fall, temperatures at the college station were sometimes above freezing, while at the orchards the temperatures were low enough to cause serious injury.

On May 12, 1938, two weeks after an early bloom, the temperature at the college station went down to 31 degrees. Peaches and apples in a nearby plantation were uninjured. At the orchard the thermometer reached 26 degrees, and 90 per cent of the crop was lost. In mid-October in both 1937 and 1939 unpicked fruit was badly frozen on several occasions when temperatures at the college station were from 24 to 28 degrees; such temperatures occurring in the orchard do only slight damage. In the most damaging freeze of 1937, occurring on October 16 and 17, the minimum temperature on the first morning was 24 degrees at the college station, and 20 degrees at the orchard; on the second morning it was 25 degrees at the college station, and 19 degrees at the orchard. On October 18, 1939, the minimum temperature at the college station was 24 degrees, and at the orchard it was 20 degrees.

At the same time that daily records were kept at the farm buildings, maximum and minimum thermometers (Sixe's pattern) were also distributed to a number of positions throughout the college orchards.

The positions of these thermometers are designated on the chart by crosses (Fig. 1). The thermometers were in most cases tied to small trees about 4 feet above the ground; in two cases they were attached to posts. There was some discussion as to whether the thermometers should be set within instrument shelters; but it was felt that, if they were placed in the trees, they would be under the same conditions that affect the trees and the fruit. In most cases they were attached to small trees, where there was a maximum exposure to the elements, or to trees with open trunks, where they would be least affected by the foliage. They have been read and set about once a week, and more often during critical periods in the spring and fall. The minimum readings thus represent not average daily conditions, but minima during critical periods.

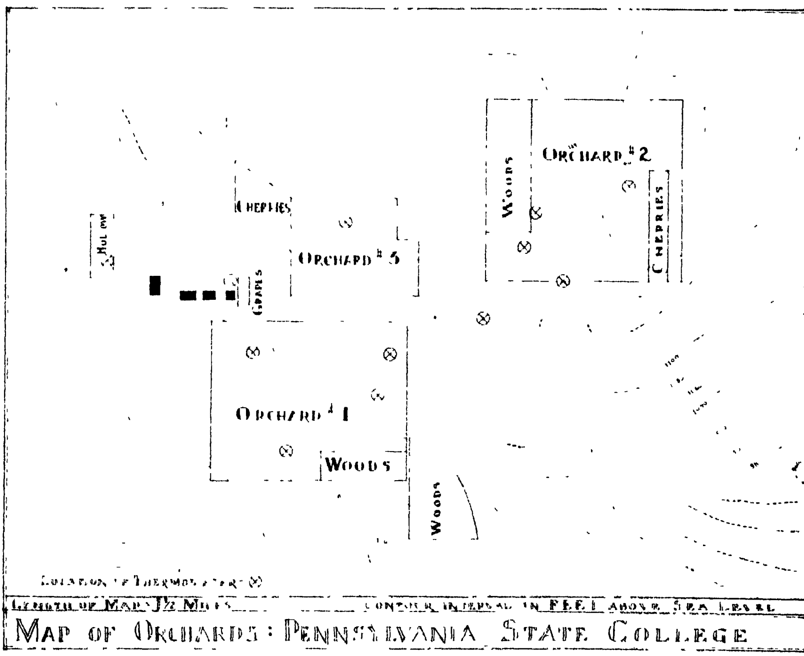

Fig. 1. Map of Pennsylvania State College orchards, showing contours and temperature stations.

Most of our fruit land is in two main plantations about a quarter of a mile apart and separated by a large, level field. The orchard across the road from the buildings is designated as orchard No. 1; the farther one is designated as orchard No. 2. According to the eye, both orchards appear to be at the same elevation; but according to topographic surveys, orchard No. 2 lies on land of which the maximum elevation is 40 feet higher than that of orchard No. 1.

Orchard No. 1 lies on the summit and on the upper south-east slope of a slight ridge. To the north-west and west the land slopes gently

toward the arms of a narrow valley which, one-half mile away, is 100 feet lower in elevation. The country is open, and there are no windbreaks. To the north and north-east is a large level field of the same altitude as the highest part of the orchard. To the south-east the land slopes gently toward the narrow arm of a broad valley and creek bottom about a mile away and 150 feet lower in elevation. Drainage of air into this arm of the valley is partially blocked by two small wood lots at the corner of the orchard.

Orchard No. 2 is on the same ridge as orchard No. 1, but its highest point is 40 feet higher. To the north and north-west is somewhat rolling country. A fence row of trees bounds the orchard on most of its north-west side. On the south-west side is a tract of woodland of about 10 acres. It has definite value as a windbreak for west and south-west winds over half the area of the orchard. However, most of the severe freezing weather comes with the wind from the north-west, north, or north-east; and data taken during a spring freeze show that the woods have little influence over the temperatures of the orchard as a whole under such conditions. The land slopes moderately to the south-east and quite steeply on the east and north-east to a creek bottom and valley about a half mile wide and with an altitude 200 feet lower than the highest point in the orchard. This slope is all pasture land, and there are no woods or other interferences to air drainage.

The minimum temperatures in orchard No. 1 have been consistently lower than those in orchard No. 2. In three years of time and with over 200 records the minima in orchard No. 1 have averaged 2.13 degrees F lower than those in No. 2, and in some instances they were much greater. These differences have at times had a marked effect on the set of fruit and on the quality of the fruit harvested. In the freeze of May 12, 1938, which occurred 2 weeks after bloom, the temperatures on two thermometers in orchard No. 1 were 25 and 26 degrees, and nearly all the fruit in this orchard was killed. In the western end of orchard No. 2 the minimum temperature was 28 degrees, and most of the fruit was killed. Toward the eastern end, at the highest point in the orchard, the minimum was 29 degrees, and here a block of McIntosh set a good crop of fruit, and an adjoining block of Stayman, which was having an off-year, set a small crop. Most of the fruits which survived were in the interior of the trees, where they were somewhat protected by the foliage.

The tract of woodland on the western border of orchard No. 2 has had a sheltering influence only on the orchard trees near it. In this same freeze of May 12, 1938, the Baldwin trees within two or three rows of the wood lot set a moderate crop, while the rest of the block had nothing. A thermometer subsequently set up beside the woods showed that night temperatures were generally 2 or 3 degrees higher here than at a thermometer a few tree rows away, and the difference was sometimes as much as 5 degrees. The fact that the influence of the woods affected the set of fruit for only three tree rows leads us to the conclusion that it has only a limited effect in moderating the temperatures of this orchard, and that the most important factors in the higher minimum temperatures of orchard No. 2 are the greater actual ele-

vation of the orchard, along with the greater opportunity for air drainage.

Across the road from orchard No. 1 lies a small plantation known as orchard No. 3, in which the trees are now about 12 years old. Through the center of this plantation is a shallow depression which leads into a steep hollow half a mile away. The low point of this depression in orchard No. 3 is about 20 feet lower than the high point of the adjacent orchard No. 1. This depression is a passage way for cold air to drain, and the narrowness of the valley, which is also winding and covered in places with trees, evidently retards the air drainage.

Temperatures here have been low enough to have a serious effect on fruit production. With over 200 readings in 3 years the minima in orchard No. 3 have averaged 0.91 degree F lower than those of orchard No. 1, and 3.04 degrees lower than those of orchard No. 2. In orchard No. 3 a block of Montmorency cherry trees 12 years old has had only one substantial crop, and a block of Saint Medard has never borne more than a few scattered cherries. In orchard No. 2 a block of cherry trees ¾ of a mile away, where the minimum temperatures have averaged 3 degrees higher, has yielded several commercial crops of Montmorency and three crops of Saint Medard during the same period. In April and May, 1939, at ten critical periods the minima in orchard No. 3 ranged from 2 to 8 degrees lower than those of orchard No. 2; in orchard No. 3 there were practically no cherries, and in No. 2 there was a full crop. The most damaging freeze during this period occurred on May 3 and 4, just before bloom, when the minimum temperatures in orchard No. 3 reached 24 and 25 degrees respectively; in No. 2 they reached 32 and 30 degrees on the same dates.

The apple trees in orchard No. 3 have been somewhat affected by the low minimum temperatures. In 1935, 1937, and 1939 they bore full crops; but in 1936 they bore practically nothing, while other blocks of trees bore fair crops. Again in 1940 the crop was reduced by late freezes. One damaging freeze came on May 12, just before bloom, when the lowest temperature reached here was 24 degrees; and in other blocks it ranged from 25 to 27 degrees, with no appreciable loss of fruit. At the time this orchard was planted, the difference in elevation between it and orchard No. 1 was not thought to be important.

One small plot of Stayman trees was planted in a narrow valley just below the farm buildings. It is designated as the Hollow orchard. It is about 50 feet lower than the rest of our orchard land. It is an arm of a valley half a mile away, and both the main valley and its branches have steep slopes for several miles; air drainage is comparatively poor. This hollow has the richest soil on any of our property, but the low temperatures have made it worthless as an orchard location. With over 200 readings in 3 years the minimum temperatures here have averaged 3.04 degrees lower than those at the house one-tenth of a mile away, and the deviation has been as much as 10 degrees. The trees have had only two small crops of fruit in 12 years.

In 1937 the crop of Stayman fruit was so badly frozen that it was not harvested. On October 16 and 17 the minimum temperatures in the Hollow orchard reached 20 and 18 degrees respectively; the fruit

showed brown streaks inside. In orchard No. 1 the minimum temperatures reached 20 degrees on both dates; the unharvested Stayman fruits were rendered somewhat spongy, but they did not turn brown. They recovered sufficiently to be salable at a reduced grade. In orchard No. 2 the minimum temperatures reached 23 degrees on those dates, and Stayman apples were not appreciably affected. The difference between 20 and 18 degrees on one morning was evidently sufficient to cause the fruit at the lower temperature to suffer killing of the tissues.

An orchard itself has something of the character of a wood. One thermometer is set on a fence post in a large, level field between orchards Nos. 1 and 2. Its minimum temperatures have averaged 1.77 degrees lower than the average minimum temperatures of orchard No. 1, and 3.90 degrees lower than those of No. 2. On a still, clear night the lowest temperature reached on any of the thermometers is often recorded in this field.

The data recorded in this paper show that minimum or damaging temperatures in orchards are not likely to be the same as those of the nearest weather station or even those at the farm buildings in connection with the orchards, and that considerable deviations may occur within one orchard. They also show how apparently minor differences in orchard sites may have a very large effect on the relative freedom or liability of the trees to frost damage. There is apparently need for more extensive studies on the frost and freezing hazards of orchard sites.

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Soil Moisture Variations in Relation to Conservation Practices in the Peach Orchard (Preliminary Report)

By John T. Bregger and Joe B. Howie, *U. S. Soil Conservation Service, Clemson, S. C.*

ONE of the more difficult phases of horticultural research deals with soil moisture studies under orchard conditions. Soil and moisture variations are not only wide but obscure, due to many factors relating to both the soil and the trees. The present status of orchard soil moisture research has been well reviewed by Magness (1), who emphasizes the need for more information on the effect of soil management practices on moisture supply. While certain conservation practices have been shown by various workers to have decreased the soil moisture and indirectly curtailed the growth and production of fruit trees under some conditions, it has been indicated by Bregger and Musser (2) that with ample storage of subsoil moisture on good fruit sites, the competition of summer cover crops is not as serious a factor as had formerly been considered.

Further observations in commercial peach orchards, where continuous cover cropping has completely or partially replaced the conventional cultivation program, indicate quite clearly that moisture competition is rarely an important factor where the soil is deep. Levels of soil moisture were studied under cover versus cultivated conditions in the W. C. Bishop Elberta peach orchard (18-years-old) during 1940, using the Bouyoucos gypsum block apparatus as well as random soil samples for oven drying. Data are presented which show that although an annual lespedeza cover crop lowered the soil moisture more than occurred under cultivation, down to and including the 15-inch depth, tree behavior and fruit growth are not significantly affected. This situation represents a deep soil site where soil moisture readings at the 2-foot depth were almost identical in both plots and apparently sufficient for the trees in spite of a 15-inch rainfall deficiency at the harvest period. However, the lespedeza plot showed a greater increase of moisture at the 2-foot level following a heavy rain due to decreased run-off.

Moisture equivalent data collected in the above orchard show significant differences in soil texture at the 8- and 15-inch depths due to contour cultivation. This indicates the importance of securing some kind of soil texture data in order to eliminate or measure some of the variability of soil sampling. The soil in the tree rows at the 8- and 15-inch depths had a definitely lower field capacity than in the row middles, while this difference did not appear at the 24-inch depth.

Data are presented from the 2-year-old experimental peach orchard, near Clemson, South Carolina, where a large number of cover crop treatments are in effect. At locations where tree roots had not penetrated, the moisture differences between fallow and cover crop treatments were significant at the 8- and 15-inch depths, but not at 24 inches. A heavy crop of Sudan grass and soybeans lowered the soil moisture level during the period of maximum growth, but utilized

significantly less moisture than Kobe lespedeza during the remainder of the growing season.

Preliminary data dealing with the effects of the terrace profiles on soil moisture are also presented. Trends were evident showing a definitely earlier and quicker drying out of the soil in the terrace ridge following rains, especially in late summer, which indicated that more tree roots were present in this location. Later examination proved this to be true; in fact, the ridge was often entirely filled with roots of the 2-year-old trees, some of them over 12 feet long. Soil moisture data taken the previous season, when roots were not present midway between the trees, show as favorable moisture conditions for tree growth in the ridge as at any other on the terrace profile. The location for maximum conservation of rainfall run-off at a depth suitable for the roots of a 1-year-old tree appeared to be under the ridge of a small plow-built terrace where a moisture level close to field capacity was maintained during a three weeks drought. Moisture equivalent data show the terrace ridge to be made up of coarser-textured soil than other locations. In a humid climate this condition would also be associated with better soil aeration in the early spring, which could in turn promote earlier root activity and tree growth.

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The Effect of Different Methods of Soil Management upon the Potassium Content of Apple and Peach Leaves

By CLARENCE E. BAKER, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

CHEMICAL analyses of leaves from terminal shoots, taken at several periods during the growing season, have been made in connection with soil management experiments with both apples and peaches. As reported previously, (1, 2), an outstanding feature of this study with apples at Lafayette is the high potassium content of leaves from trees grown in sod with a mulch collar of strawy manure. Leaves from such trees contained more potassium than leaves from trees in cultivation to which 10 pounds of KCl had been applied to the soil.

This study was extended to include mature Grimes apple trees recently changed from cultivation to bluegrass sod and to sod supplemented with straw mulch. Leaf samples also were collected from four peach orchards in which soil management studies were being carried on in 1939, and in one additional orchard in 1940. The results reported here cover only the 1939 and 1940 seasons.

LEAF ANALYSES

The results for each treatment for apples as shown in Table I are based upon a sample of 80 leaves per tree from each of two trees. The trees were 16 years old in 1939, and all trees are in the same orchard. The peach orchards in which studies are being made are of different ages and in different locations. In the bearing Plass orchard a sample of 40 leaves was taken from each of four trees in each treatment. The young Byers, Holden, and Johnson orchards were in their second year's growth in 1939 and each analysis is based upon a sample of 20 leaves from each of eight trees. In the Bolten orchard, where the trees were in their fourth growing season in 1940, a sample consisted of 30 leaves from each of six trees.

Leaves from the middle portion of shoots of the current season's growth were taken in all cases to insure securing leaves of similar age and function in order that comparisons could be made between treatments within each orchard on each sampling date. Several samples were taken over the growing season to observe changes that took place during the summer.

The leaf samples were dried in a ventilated electric oven at 85 degrees C, ground in a ball mill and potassium determinations were made following the methods of Wilcox and Sideris as combined by Batjer and Magness (3). All results are expressed as per cent of dry weight.

The results for apples (Table I) show the high potassium content of leaves from trees mulched with strawy manure since 1934 (plots A-E and A-W) in comparison with the plots in cultivation and sod.

The effect of a straw mulch is likewise interesting as shown in plots E-G and E-S. These are adjacent plots and both are part of a larger

area that was cultivated for 14 years but received no nitrogen or other fertilizer. The soil was seriously eroded and the trees were in an extremely devitalized condition when this area was seeded to grass in the spring of 1937. A nitrogen fertilizer also was applied that spring for the first time. In the spring of 1938 half of these trees were given a mulch collar of two bales of straw per tree and an additional bale was added in the spring of 1939 (plot E-S). Plot E-G is composed of the trees that were continued in a sod plus nitrogen treatment but received no mulch. The increased potassium content of the leaves from trees to which straw was applied (plot E-S) is quite outstanding, especially during 1940, in comparison with the area in sod without mulch (plot E-G).

In general trees in cultivation to which KCl was applied alone or in combination with superphosphate or sulphate of ammonia do not show as much potassium in their terminal leaves as trees mulched with straw or strawy manure. The application of KCl to the soil increased the potassium content of the leaves to a limited extent in some instances, especially when used alone, but in most cases there has been no significant increase.

An inorganic mulch of spun glass wool was used on one area (plots B–11–E and B–11–W) to give a direct comparison with the organic mulches, straw and strawy manure. The glass wool exerts comparable physical effects, such as shading, checking evaporation, and encouraging the penetration of rainfall, but adds no plant food elements to the soil. While the potassium content of leaves from trees under the glass mulch is higher than in the case of some of the treatments presented, this treatment does not give the increases that follow the use of straw or manure.

Discussion

While it is not within the province of this paper to account for the reasons for these results, several possible explanations present themselves: (a) The straw or strawy manure mulch may furnish a directly available supply of potash, either through the leachings from the mulch or from the decaying organic matter in contact with the soil. (b) Conditions beneath the mulch may be more favorable for making available the potash already in the soil. (c) Conditions beneath the mulch may be more favorable for root growth so that a greater area of soil is explored by the roots and consequently more potash is taken into the tree. If mulching responses result from physical factors alone, an inorganic mulch should be as effective as an organic one.

It is well known that trees mulched with straw or manure send out a mat of feeding roots in the upper portion of the soil. If moisture conditions are favorable these roots often extend well up into the decaying portion of the mulch above the surface of the soil.

Root formation under the glass wool mulch does not appear to be so extensive. The small, fiberous roots are well distributed through the surface soil immediately below the mulch, but naturally they do not grow up into it as they do in straw or manure. The root formation under glass wool appears to be more comparable to that under sod.

The trees in the plots mulched with strawy manure (plots A-E and A-W, Table I) are vigorous and produce large amounts of high quality fruit. When mulching was begun in 1934 these trees were very weak and unproductive. Since that time they have changed from the least vigorous and lowest yielding to the most productive trees in the series of plots. In 1940 trees under this treatment were the only ones in the orchard that consistently produced a heavy crop following the heavy crop of 1939.

The trees in plot E to which straw was applied in 1938 (E-S, Table I) are making a rapid recovery; more rapid than the trees in sod without the mulch (E-G).

None of the trees, even those where the potassium content of the leaves was very low, showed leaf scorch or other definite symptoms of potassium deficiency during 1939 or 1940.

The data for phosphorus and nitrogen is not presented in this paper. With apples no significant increases either in nitrogen or phosphorus has been found following the use of organic mulches.

The figures for potassium in Table I give further evidence of the

TABLE I—POTASSIUM IN PER CENT OF DRY WEIGHT OF LEAVES OF GRIMES APPLE TREES UNDER DIFFERENT SYSTEMS OF SOIL MANAGEMENT (LAFAYETTE, INDIANA)

Plot	Fertilizer Treatment*	Per Cent K (1939)				Per Cent K (1940)		
		May 21	Jun 22	Aug 9	Oct 12	Jun 4	Jul 8	Sep 13
		Cultivation						
B-7 E	O	1 76	1.65	1 19	1.02	1 48	1.51	1 23
B-7-W	N	1.35	1.07	0.86	0.73	1.05	0.95	0.60
B-8-E	P+K	1 70	1.44	1.07	0.84	1 45	1 41	1.23
B-8-W	P+K+N	1.47	1 26	1.08	0.86	1.29	1.19	0.81
B-9-E	P	1.72	1.69	1.46	1.04	1.41	1.53	1.32
B-9-W	P+N	1 40	1.12	0.77	0.65	1.02	1.02	0.73
B-10-E	K	1 91	1.55	1.23	1.00	1 47	1.55	1.37
B-10-W	K+N	1.71	1.26	1.08	0.90	1.42	1.22	1.01
		*Glass Wool Mulch***						
B-11-E	O	1.85	1.84	1 30	0.92	1 56	1.80	1.62
B-11-W	N	1.37	1.11	0.82	0 58	1.36	1 19	1.04
		Sod						
C-E	N	1.61	—	1.27	1.08	1.44	1.55	1.37
C-W	N	1.69	1.65	1.36	1.08	1.53	1.38	1.23
		Strawy Manure Mulch†						
A-E	O	2.46	2.04	1.37	1.19	2.12	1.85	1.50
A-W	N	2.14	1.81	1.37	1.23	1.83	1.61	1.09
		Sod‡						
E-G	N	1.53	1.42	1.23	0.95	1.59	1.42	1.31
		Straw Mulch§						
E-S	N	1.91	2.12	1.47	1.03	2.06	2.14	1.74

*N = Annual spring applications of sulphate of ammonia; P = 15 pounds superphosphate per tree applied in 15 soil auger holes 18 inches deep, 1 pound per hole, April 12, 1938; K = 10 pounds KCl per tree on surface beneath branches and disced in, applied April 12, 1938; O = no chemical fertilizer used.

**An inorganic mulch of glass wool 3 inches thick 20 × 20 feet square applied beneath tree. Area between trees in bluegrass sod. This treatment started in April, 1938, with cultivation previous to that time.

†Strawy manure mulch since fall of 1934, previously cultivated.

‡Cultivated until spring of 1937. Area between trees then seeded to bluegrass.

§First straw applied in spring of 1938, two bales per tree.

effect of nitrogen application in reducing the potassium content of the leaves. This difference is quite consistent, especially on the earlier sampling dates each season. This interaction of N and K has been reported by several investigators (4, 5, 6, 7).

Results of Mulching Peach Trees

In the case of peach trees mulching with straw or alfalfa increases the potassium content of terminal leaves in the same manner as has been described for apples. The result of two years' study in five orchards is presented in Table II. Because of differences in location soil type, and age of trees, comparisons between orchards is not possible, but the mulched and unmulched plot in each orchard may be compared directly. With very few exceptions the amount of potassium found in leaves from mulched trees was greater than that found from unmulched trees in the same orchard on the same sampling date. In many instances these differences are striking.

With the young trees in the Byers, Holden, and Johnson orchards the difference in size and vigor of the mulched trees is very obvious. This is especially noticeable in the Byers orchard, which is on a fine sandy loam soil. The mulched trees in this orchard came through a dry period in 1939 in excellent condition, while the unmulched trees suffered from lack of moisture. The mulched trees hold their foliage

TABLE II—Potassium in Per Cent of Dry Weight of Leaves of Peach Trees Under Different Systems of Soil Management

Treatment*	Per Cent K 1939					Per Cent K 1940				
	May 16	Jun 20	Aug 11	Sep 6	Oct 6	May 20	Jun 12	Jul 15	Aug 14	Sep 10
					Plass Orchard—Eroded Clay					
Check (1)	2.12	1.87	1.46	1.38	1.31	1.86	2.02	2.15	2.03	1.95
Mulch (2)	2.20	1.81	1.44	1.47	1.28	1.99	2.07	2.19	2.02	1.98
					Byers Orchard—Fine Sandy Loam					
Check (3)	1.66	1.77	1.51	—	—	1.80	1.98	1.97	1.84	1.73
Mulch (3, 4)	2.59	2.76	2.58	—	—	2.37	2.40	2.62	2.23	2.22
					Holden Orchard—Eroded Clay					
Check (5)	1.78	1.55	1.95	1.57	1.44	1.47	1.51	1.37	1.34	1.24
Mulch (5, 6)	2.11	2.26	2.24	1.99	1.77	1.96	2.19	2.01	1.97	1.61
					Bolten Orchard—Clay Loam					
Check (7)	—	—	—	—	—	1.30	1.57	1.25	1.20	1.23
Mulch (8)	—	—	—	—	—	1.21	1.57	1.67	1.58	1.52
					Johnson Orchard—Clay Loam					
Check (9)	1.24	0.65	0.85	0.85	0.72	1.45	1.36	1.16	1.06	0.85
Mulch (10)	1.27	1.08	1.24	1.34	1.11	1.84	1.94	1.88	1.78	1.61

(1) Lespedeza sod, hand cultivation around trees.
(2) One bale of straw per tree in spring of 1938; no mulch since.
(3) Rye and soybean cover crops between trees.
(4) One-half bale of straw spring 1938, one-half bale spring 1939, one-half bale spring 1940.
(5) Rye and soybean cover crops between trees.
(6) One-half bale of straw per tree in spring of 1938, one-half bale fall of 1938, one-half bale spring 1940.
(7) Rye and soybean cover crops between trees.
(8) One bale of straw per tree May 10, 1940, one bale per tree spring of 1941; Lespedeza sod between trees.
(9) Trees in alfalfa sod with some hand cultivation around trees.
(10) Trees mulched with alfalfa cut from area about trees.

longer in the fall, and in the spring of 1941 the spur formation and abundance of bloom was much in favor of the mulched trees.

The Plass orchard received one bale of straw per tree in the spring of 1938 and no further applications have been made. The orchard is in lespedeza which is cut and raked about the trees, forming a light mulch. As the check plot was treated in this manner it also has had some mulch while the small amount of straw applied to the other plot has not provided an adequate mulch. This combination of factors probably accounts for the little difference in potassium content of leaves from the two plots.

The Bolten orchard was mulched for the first time 10 days before the first leaf sample was taken on May 20, 1940. Starting at a slightly lower figure than that for the check plot, the potassium content of leaves from the mulched trees soon equaled and later surpassed the leaves from the check plot during the first season of mulch treatment.

In all cases, with both apples and peaches, as has frequently been reported, the potassium content of leaves from shoots of the current seasons growth tends to be highest on the earlier sampling dates, falling to lower levels during the season. This tendency also occurs on mulched trees but in the case of peaches (Table II) in many instances the potassium content of leaves from mulched trees was higher on the latest sampling date than that of leaves from the comparable unmulched trees on the earliest date.

With peaches there is more indication of a slight but rather consistent increase in phosphorus in leaf samples from mulched trees in comparison with those from the corresponding check plots.

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The Effect of Soil-Management Methods on Certain Physical and Chemical Properties in Relation to the Infiltration Rates in West Virginia Orchards[1]

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DURING the past two years, work was conducted in order to determine some of the physical and the chemical properties of the important orchard soils of the Eastern Panhandle of West Virginia. A total of 63 profile samples was taken from 20 commercial orchards representing various cultural practices and types of vegetative cover for the Hagerstown, Hagerstown (yellow subsoil phase), Frankstown, Frederick, Lehew, Dekalb, and Berks series. This report briefs certain portions of the results of this study.

Procedure

Mechanical analyses were made according to the procedure outlined by Olmsted *et al.* (5). Aggregate distributions were determined by the method described by Yoder (11); the air-dry soil was passed through a 7.0 millimeter screen and the samples were allowed to slake 20 minutes on the screens before fractionation. Dispersion ratios were calculated by dividing the less than 0.05 millimeter fraction resulting from the aggregate analyses by the less than 0.05 millimeter fraction obtained after dispersion with sodium oxalate, then by multiplying the resultant decimal fraction by 100.

Specific-gravity determinations were made by the method outlined by Hillebrand (4). A California soil tube (9) was used in collecting the soil samples for the volume weight determinations. The samples were weighed, coated with paraffin of known volume weight, and reweighed; finally the volume was determined by weighing in water.

Organic-matter determinations were made by a modification of the Schollenberger (7, 8) rapid-titration method essentially as described by Wakley and Black (10). The average amount of recovery by the dry-combustion and the rapid-titration method was used as an approximate factor for correcting the values obtained for organic matter by the rapid-titration method (2).

Moisture equivalents were determined by a laboratory centrifuge equipped with trunnion cups as described by Goldbeck and Jackson (3). The speed required to give a force of 1,000 times gravity was controlled within 50 revolutions per minute by the use of an International centrifuge tachometer No. 78. Five grams of soil were weighed into Gooch crucibles fitted with filter papers, after which the procedure for saturating, draining, and centrifuging the sample was identical with that followed in determining the moisture equivalent by the Briggs-McLane method (1).

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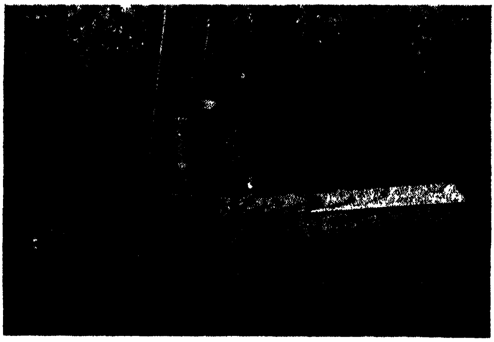

FIG. 1. North Fork infiltrometer with plot walls, run-off trough and cover, rain pan, support stakes, sprinkler head, and pump, in place ready for a calibration run except for the tent. Plot size 11x30 inches.

The moisture equivalent was used as a measure of capillary porosity and the non-capillary porosity was obtained by subtracting the moisture content by volume at the moisture equivalent from the total porosity. The total porosity in per cent was calculated with the usual formula: $\frac{A-B}{A} \times 100$, where A = real specific gravity, and B = apparent specific gravity.

Infiltration rates were determined with the North Fork type (6) infiltrometer, Fig. 1. The calculated amount of water necessary to bring the soil to the field capacity was applied with a sprinkling can. After saturating, the plots were covered with burlap bags and allowed to stand 24 hours before using the infiltrometer. Determinations were made on three separate plots and their values were averaged for each soil series; the agreement between the three figures was generally very close.

In all cases, observations with the infiltrometer were made with the rain pan in place until the results of three successive 1-minute periods checked within 5.0 cubic centimeters. The rain pan was then removed and the water was allowed to fall on the plot. Measurements of the run-off were recorded at frequent intervals until a 30-minute period was observed during which there was little or no change in its rate. In addition the total run-off was obtained for this 30-minute period, then the rain pan was replaced and three successive 1-minute readings were taken. The infiltration rate was calculated in inches per hour by subtracting the rate of run-off from the soil from that of the rain pan. All plots possessed a slope of approximately 6 per cent.

In using the infiltrometer the vegetation was clipped to a height of ½-inch on the undisturbed plot area. The disturbed areas were cultivated with a hoe to a depth of 3 inches. A 1½-inch layer of wheat straw was used in studying the effect of mulching on losses of soil and water.

Physical and Chemical Properties

Aggregation:—Limestone soils were found to be higher than sandstone and shale soils in the percentage of aggregates greater than 0.25 mm for both the surface and the subsoil samples. This may be explained as due to the presence in the limestone soils of a larger amount of organic matter and clay, both of which are instrumental in binding the individual soil particles into larger-sized aggregates.

Considering the effect of cultural treatments on aggregation, it was evident that surface samples from the sodded sites are more highly

aggregated than are those from the cultivated sites. Cultivation has materially reduced organic matter. The mechanical process involved in cultivation is also destructive to aggregates. Therefore, it is logical to find a less desirable structure in the cultivated sites than in the sodded areas.

In Tables I and II, aggregation is expressed by grouping together all aggregates greater than 0.25 mm. Such a grouping does not take into consideration differences that may exist in the 2, 1, 0.5, and 0.25 mm fractions and which have an influence on the water relationships of the soil.

The effect of cultivating and of disturbing the soil has been to increase the smaller-sized fractions at the expense of the larger-sized fractions. Data which are not given elsewhere in this report show that cultivation has decreased the greater than 0.25 mm fraction of soil particles and aggregates of the surface soil from 69.9 to 25.9 per cent in the Dekalb, from 52.5 to 43.9 per cent in the Lehew, and from 81.0 to 64.8 per cent in the Berks. With the limestone soils the percentage dropped from 65.4 to 50.6 in the Hagerstown, 85.1 to 61.4 in the Hagerstown (yellow subsoil phase), 75.6 to 45.6 in the Frederick, and from 68.7 to 52.4 in the Frankstown.

The results for the subsoil samples were similar to those found in the surface, although the general trend is for the differences in the subsoil under sod and under cultivation to be somewhat less than in the surface soil. Since in this Cumberland-Shenandoah Region most of the grass roots are located in the surface soil and the organic-matter content in the surface soil is much higher than in the subsoil, the structural conditions of the subsoil are influenced to a larger extent by the inorganic colloidal fraction.

In silt loam soils the amount of inorganic colloidal material is limited and the degree of aggregation will be influenced largely by the organic-matter content.

In general clay soils will be influenced less by changes in organic matter than silt loams, while sandy soils will be affected the least. With all of the soils in the study, the texture is such that organic matter plays a major role in the development of a structural condition conducive to the maximum absorption and hence to the minimum losses of water.

Dispersion Ratio:—Since a state of high aggregation means a low dispersion ratio and *vice versa,* differences between the dispersion ratios of the sod and of the cultivated areas are to be expected. Table I shows that cultivation has increased the dispersion ratio of the surface soil from 26.9 to 79.1 in the Dekalb, 45.6 to 63.6 in the Lehew, 20.9 to 24.5 in the Berks, 20.3 to 31.9 in the Hagerstown, 5.7 to 23.1 in the Hagerstown (yellow subsoil phase), 14.8 to 42.7 in the Frederick, and 25.3 to 33.2 in the Frankstown.

The differences in the subsoil dispersion ratios of the sod and of the cultivated areas were small, and probably they are not significant in the case of the Dekalb, Lehew, Berks, and Hagerstown soils. On the other hand, the subsoil of the cultivated areas of the Hagerstown (yellow subsoil phase), the Frederick, and the Frankstown showed

TABLE I—THE EFFECT OF PAST CULTURAL TREATMENT AND VEGETATIVE COVER ON THE PHYSICAL AND CHEMICAL PROPERTIES OF SURFACE SOIL*

Cover	Specific Gravity	Volume Weight	Total Porosity (Per Cent)	Moisture Equivalent	Non-Capillary Porosity (Per Cent)	Dispersion Ratio	Organic Matter (Per Cent)	Aggregates >0.25 Mm (Per Cent)
				Dekalb Shale Silt Loam				
Sod	2.64	0.97	63.3	27.5	35.8	26.9	4.5	52.9
Cult	2.69	1.54	42.8	31.9	10.9	79.1	1.3	12.3
				Lehew Gravelly Fine Sandy Loam				
Woods...	2.60	1.51	41.9	32.0	9.9	45.6	4.0	40.3
Cult.....	2.69	1.67	37.9	22.7	15.2	63.6	1.3	25.6
				Berks Silt Loam				
Sod ...	2.65	1.08	59.4	29.6	29.8	20.9	3.2	45.2
Cult.....	2.59	1.45	44.0	29.1	14.9	24.5	2.8	40.8
				Hagerstown Silt Loam				
Sod	2.56	1.26	50.8	31.9	18.9	20.3	4 5	59.4
Cult .. .	2.64	1.46	44.7	29 8	14.9	31.9	2.2	42.2
				Hagerstown Silty Clay Loam (Yellow Subsoil)				
Sod	2.61	1.22	53.3	33.4	19.9	5.7	4.1	83.1
Cult.....	2.62	1.52	42.0	28.0	14.0	23.1	2.9	46.5
				Frederick Silt Loam				
Sod	2.58	0.90	65.1	25.6	39.5	14.8	4.7	63 6
Cult.....	2.72	1.34	50 7	37.5	19.2	42.7	2.3	30.7
				Frankstown Silt Loam				
Sod......	2.64	0 98	62.8	29.7	33.1	25 3	4.0	51.5
Cult.....	2.58	1.33	48.4	32.4	16.0	33.2	3.1	39.6

*The depth of the surface soil samples varied from 3 to 6 inches.

TABLE II—THE EFFECT OF PAST CULTURAL TREATMENT AND VEGETATIVE COVER ON THE PHYSICAL AND CHEMICAL PROPERTIES OF THE SUBSOIL

Cover	Specific Gravity	Volume Weight	Total Porosity (Per Cent)	Moisture Equivalent	Non-Capillary Porosity (Per Cent)	Dispersion Ratio	Organic Matter (Per Cent)	Aggregates >0.25 Mm (Per Cent)
				Dekalb Shale Silt Loam				
Sod......	2.68	1.70	36.8	36.5	0.3	57.3	1.4	19.5
Cult.....	2.69	1.64	39.0	34.6	4.4	54.0	0.6	15.5
				Lehew Gravelly Fine Sandy Loam				
Woods...	2.65	1.72	36.3	32.7	3.6	56.9	1.0	31.1
Cult.....	2.69	1.80	33.2	24.1	9.1	56.9	0.3	36.1
				Berks Silt Loam				
Sod	2.71	1.53	43.3	36.7	6.6	23.1	1.2	29.7
Cult.....	2.65	1.55	41.5	40.4	1.1	26.9	1.0	23.6
				Hagerstown Silt Loam				
Sod......	2.63	1.48	43.7	33.7	10.0	41.7	0.9	36.4
Cult.....	2.68	1.58	41.0	28.8	12.2	36.4	0.9	26.9
				Hagerstown Silty Clay Loam (Yellow Subsoil)				
Sod......	2.61	1.26	51.9	29.9	22.0	11.3	2.4	68.7
Cult.....	2.62	1.48	43.5	29.2	14.3	23.4	0.8	48.2
				Frederick Silt Loam				
Sod......	2.64	1.24	53.0	30.5	22.5	17.7	1.8	61.4
Cult.....	2.65	1.38	47.9	29.5	18.4	30.0	0.4	16.8
				Frankstown Silt Loam				
Sod......	2.55	1.32	48.2	33.7	14.5	36.4	1.3	22.9
Cult.....	2.55	1.35	47.1	33.1	14.0	45.5	0.5	17.4

definitely higher dispersion ratios than did the sodded areas.

Other Physical and Chemical Data:—The effects of past cultural treatment and of present vegetal cover on certain of the physical and chemical properties of the surface and of the subsoil in typical orchards are shown in Tables I and II, respectively. No significant differences were found in the specific gravity of the sod and of the cultivated sites either for the surface or for the subsoil.

The volume weights for the surface soil of the sodded and of the cultivated areas, respectively, were 0.97 and 1.54 for the Dekalb, 1.51 and 1.67 for the Lehew, 1.08 and 1.45 for the Berks. In the case of the limestone soils, the volume weights were 1.26 and 1.46 for the Hagerstown, 1.22 and 1.52 for the Hagerstown (yellow subsoil phase), 0.90 and 1.34 for the Frederick, and 0.98 and 1.33 for the Frankstown. In the case of the subsoil there is little or no significant difference in the volume weights of the cultivated and of the sodded areas.

From the method of arriving at the total porosity from the specific gravity and from the volume weight, it follows that a difference would be found in the total porosity of the surface soil, because, as the specific gravity is essentially the same in all the soils studied, the total porosity will increase as the volume weight decreases.

The moisture equivalents on the volume basis are shown in column 6, Tables I and II. The differences in the moisture equivalents between the sodded and the cultivated sites were generally small and they can be explained on the bases of the differences in organic matter, the structural changes resulting from cultivation, and the consequent depletion of organic matter, the textural variations of the parent materials, or the differential removal of soil particles by erosion. The results are expressed on the volume basis; that is, the moisture equivalents by weight were multiplied by the volume weights, since the data were to be used in calculating the non-capillary porosity.

It is evident from the data on non-capillary porosity, as shown in Table I, column 7, that cultivation has decreased materially the non-capillary porosity of the surface soil. The percentages of the non-capillary porosity for the sodded and for the cultivated sites, respectively, were 35.8 and 10.9 in the Dekalb, 9.9 and 15.2 in the Lehew, 29.8 and 14.9 in the Berks, 18.9 and 14.9 in the Hagerstown, 19.9 and 14.0 in the Hagerstown (yellow subsoil phase), 39.5 and 19.2 in the Frederick, and 33.1 and 16.0 in the Frankstown. In the subsoil the differences were small and probably they lack significance. In general, the values for non-capillary porosity were much lower for the subsoils than for the surface, which is in accord with the lower total porosity and the higher volume weights for the same subsoils.

Cultivation has decreased the organic-matter content both in the surface and in the subsoil as shown in column 9 of Tables I and II, respectively. In the surface soil, the percentage of organic matter for the sodded and for the cultivated sites, respectively, were 4.5 and 1.3 in the Dekalb, 4.0 and 1.3 in the Lehew, 3.2 and 2.8 in the Berks, 4.5 and 2.2 in the Hagerstown, 4.1 and 2.9 in the Hagerstown (yellow subsoil phase), 4.7 and 2.3 in the Frederick, and 4.0 and 3.1 in the Frankstown. The same general trend is to be observed in the subsoil,

although the organic-matter content was less and the differences between the cultivated and the sodded sites were much smaller.

It is evident, therefore, that past cultural treatments, especially if intensive and long-continued, have a very important effect upon the physical and the chemical properties of the soil. If a soil is allowed to remain in an undisturbed sod, a desirable soil structure, conducive to the rapid absorption of water and to little, if any, soil erosion, is built up or maintained. On the other hand, cultivation tends to deplete the organic-matter content, to increase the percentage of the smaller-sized aggregates at the expense of the larger-sized ones, and in general to leave the soil in a physical condition which is conducive to rapid losses of soil and water.

Clean tillage temporarily increases biological activity, and therefore the tendency is for the organic-matter content to decrease, unless unusually good soil management practices are followed. If the soil is cultivated, the securing of the heaviest practical growth of cover crops, the incorporation of organic residues from outside sources whenever possible, or the adoption of a sod rotation including both legumes and a close-growing type of vegetation, will help maintain desirable structural conditions, and at the same time these practices will reduce the losses of soil and water.

Infiltration Rates:—The effects of vegetal cover, tillage, and mulching on the relative infiltration rates were studied on a few areas. In Table III is shown the effect of tillage on the infiltration rate of the

TABLE III—THE EFFECT OF CULTIVATION AND MULCHING ON THE INFILTRATION RATE

Soil Type	Infiltration Rate (Inches Per Hour)		
	Cultivated in Past	Cultivated 3 Inches Deep Recently	Cultivated 3 Inches Deep and Mulched Recently
Dekalb shale silt loam	1.75	0.16	2.20
Hagerstown silt loam.	0 67	0 59	1.80
Frankstown silt loam . . .	1.18	0.24	1.18
Berks silt loam (shallow phase) .	0 06	0.06	—
Lehew gravelly fine sandy loam	1.31	0.49	—

Lehew, Dekalb, Berks, Hagerstown, and Frankstown soils. The sites selected for the study have received some cultivation in the past, consisting of several diskings every year. In recent years this practice has been discontinued generally, and volunteer native vegetation has been allowed to grow. The amount and the type of cover at present are quite variable, depending upon the soil series and upon the previous soil treatment. In most cases relatively good numbers of soil-protecting plants were present.

Before determining the infiltration rate with a North Fork infiltrometer, the vegetation present was removed in all instances by close clipping, and on each of the five series one site was cultivated 3 inches deep with a hoe. As Table III shows, cultivation of the surface 3 inches has decreased the infiltration rate in inches per hour from 1.31 to 0.49 in the Lehew, 1.75 to 0.16 in the Dekalb, 0.67 to 0.59 in the Hagers-

town, 1.18 to 0.24 in the Frankstown soil, while the Berks soil has remained unaffected by cultivation.

The effect of mulching with a 1½-inch layer of wheat straw following an initial 3-inch cultivation on the Dekalb, Hagerstown, and Frankstown soils is shown in Table III. Sites were employed adjacent to the areas which had been used to study the effect of tillage on the infiltration rate. After cultivating the soil to a depth of 3 inches, a straw mulch was applied and the soil was brought to the field capacity. The infiltration rates in inches per hour for the cultivated, and for the cultivated and mulched sites, respectively, are 0.16 and 2.20 in the Dekalb, 0.59 and 1.80 in the Hagerstown, and 0.24 and 1.18 in the Frankstown. As shown by the data in Table III, it is evident that when clean tillage is practiced, especially when the ground is dry, thus forming a dust mulch, and a heavy rain follows, the dispersing action of the large raindrops soon seals the surface pores, with the result that practically all of the water runs off, causing serious losses of soil and contributing little to the moisture available to the trees. A similar reaction may follow the seeding of cover crops before they can offer protection against erosion. It is evident that mulching has maintained or increased the infiltration rate over that of the uncultivated soil, while cultivation has materially reduced it. Mulching eliminates the violent dispersing action of the large raindrops striking the ground. Consequently, as the surface layer of the soil remains loose and open, this condition is conducive to a rapid intake of water.

Table IV shows the effect of previous orchard-soil management on the infiltration rate for the Lehew, Dekalb, Berks, Hagerstown,

TABLE IV—THE EFFECT OF SOIL MANAGEMENT ON THE INFILTRATION RATE

Soil Type	Infiltration Rate (Inches Per Hour)	
	Sod	Cultivated in Past
Lehew gravelly fine sandy loam	5.00+	1.31
Dekalb shale silt loam	5.00+	1.75
Berks silt loam (shallow phase)	0.06	0.06
Hagerstown silt loam	5.00+	0.67
Frankstown silt loam	5.00+	0.66
Frederick silt loam	5.00+	0.49

Frankstown, and Frederick soils. The type and the amount of cover in the sodded areas are somewhat variable but in general there are represented portions of orchards which have been subjected to no disturbance for many years. The infiltration sites were selected either between the trees, and completely out of the roadways used in orchard operations, or on relatively undisturbed areas adjoining the orchard. There has been little or no soil compaction by spray rigs or by other heavy mobile weights, and the cover has either been clipped and allowed to lie or else it has grown up, died, and fallen back on the ground. In this manner there has been a surface accumulation of organic material and a building up of a loose layer of surface soil. Worm holes, insect burrows, and channels left by decayed roots also play their part. This largely explains the rapid infiltration rate for all

of the sodded sites, except the Berks. The maximum infiltration rates of the soils other than the Berks could not be determined, since the largest nozzles available for the infiltrometer gave a maximum rate of about 5.0 inches per hour.

Sod has not increased the infiltration rate of the Berks over that of the cultivated area. The soil in this orchard was mapped as a silt loam; it had a shallow surface underlain by a compact subsoil which graded into undifferentiated parent material at a depth of 12 to 15 inches. Until the limited pore space was filled with water, the infiltration rate was relatively high. However, when once saturated, the compactness of the subsoil limited the downward movement of water, and the infiltration rate approached zero regardless of the surface treatment or cover.

The high infiltration rates of the other sods to which reference is made in this study should not be confused in any way with those of otherwise comparable areas which have been pastured, for entirely different conditions exist in pastures. In such places, the vegetal material has not been allowed to accumulate, and the tramping by the cattle has compacted the soil. This accounts, in part, for the relatively low infiltration rates in some pasture fields as observed by the junior author.

From these data it is evident that much can be accomplished in conserving water and soil in orchards by following certain soil-management practices. Moisture is often a limiting factor in orchards in the Cumberland-Shenandoah Region, especially during certain critical periods of the growing season. Water lost as run-off from intense summer rains falling on unprotected areas can be avoided, to a large extent, by adopting a system of orchard cultural management in which a minimum of soil disturbance occurs and in which an adequate soil cover is provided throughout the year to protect the surface from the dispersing action of rain. Contour planting, terracing, and diversion ditches should be considered also as supplemental practices for all proposed plantings.

Summary and Conclusions

This paper reports the effect of cultivation, past and relatively recent, and of surface mulches on certain physical and chemical properties of orchard soils in the Eastern Panhandle of West Virginia as they are integrated by the infiltration rate.

Compared with an undisturbed sod cover, cultivation has reduced materially the organic-matter content, the percentage of the larger-sized aggregates, the non-capillary porosity, and the infiltration rates; it has increased the volume weight and the dispersion ratio.

Straw mulch, by protecting the surface from the dispersing action of the water from the infiltrometer nozzles as it fell on the soil, materially increased the infiltration rate over that of the cultivated areas. Comparable protection would be afforded against beating rains.

The data emphasize the importance of protecting the soil surface with adequate vegetation or with ample organic mulches as they are related to the conservation of water and soil, both of which are highly essential to successful orcharding in the Cumberland-Shenandoah

Region. In the absence of mechanical compaction, orchards which have been in sod continuously thereby have automatically maintained favorable structural conditions which are conducive to the rapid infiltration of water with little, if any, loss of soil. In marked contrast, cultivation tends to deplete the fertility of the soil and is likely to be destructive of its desirable physical properties, thus increasing the susceptibility of the orchard site to losses of water and of soil and the liability of the trees to injury by drouth.

Acknowledgment is made for the services of Mr. Dillon S. Brown, Department of Horticulture, West Virginia University, for assistance in obtaining the soil samples.

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Rapid Determination of Potassium with Dipicrylamine[1]

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THE biologist and in particular the horticulturist with his limited populations of relatively variable material, which makes multiple sampling a necessity, desires analytical procedures which are time-saving yet give easily reproducible results even though of only moderate accuracy. It would appear profitable to have available detailed descriptions of determinations carried out in a manner to accomplish these objectives.

A number of potassium determination procedures have been proposed but the data of Kolthoff and Bendix (5) indicate that the indirect determination of potassium with dipicrylamine (hexanitrodiphenylamine) such as presented by Amdur (1) should be remarkably free of complicating reaction factors which interfere with the accuracy of most determinations. Certain concentration limits (5) of other ions must of course be observed; however, in this case the limits are comparatively wide.

A revision of Amdur's (1) procedure is presented here which offers close reproducibility with a minimum time requirement.

Only one reagent is necessary aside from potassium chloride solutions utilized for standardization. This is a lithium dipicrylaminate solution saturated with the potassium salt. Eighteen grams of dipicrylamine are dissolved in a solution of 3.3 grams of lithium carbonate in 500 milliliters of water warmed to 50 degrees C. After standing until cool, the solution is filtered and 400 milliliters diluted to 2 liters with water. To the residual portion of approximately 100 milliliters is added 0.5 gram of potassium chloride dissolved in a small amount of water. The resulting precipitate of potassium dipicrylaminate is either filtered or centrifuged off, washed with a few milliliters of water, and added to the warmed solution of lithium dipicrylaminate. After thorough shaking the resulting solution is stored in an incubator, held at a temperature closely approximating that at which the determinations are to take place. The solution is decanted as needed for use. Filtering is not necessary.

The procedure is made possible by the use of certain easily constructed equipment. The reactions are carried out in ½- by 4-inch culture tubes conveniently held in racks of 16 tubes. The racks are made by soldering the turned-down ends (¼ inch) of 6-inch pieces of galvanized wire (0.05-inch diameter) onto 2½ by 12-inch sections of 18 gauge galvanized sheet iron at intervals of ¾ inch. The wires are then wound in a spiral up around the test tubes.

An inexpensive shaker is constructed by mounting a 16-inch square piece of plyboard (⅜ inch) on a suitable base by means of two double hinges, constructed by soldering the ends of two 2½ by 2½ inch removable pin cupboard hinges together. The plyboard is mounted with the hinges in line with an accentric-driven arm which provides a horizontal shaking motion. A discarded roller bearing set ¼ inch

[1]Thanks are due to Mr. Gail Zellinger for making the chloroplatinate determinations.

off center by an appropriate wood bushing is mounted on an inexpensive polishing and grinding head. A strip of ⅛ by ¾-inch strap iron is soldered to the edge of the bearing and is connected by a bolt to a 1-inch upright section of angle iron mounted on the plyboard. A 9-inch pulley on the head and a 1-inch pulley on the motor provides an appropriate shaking action.

Filtering of the solution is carried out by dropping sintered glass filter sticks into the small test tubes. Finely powdered pyrex glass is sintered at about 78 degrees C for 15 minutes in 4 millimeter sections of 10 millimeter inside diameter brass tubing. Samples should be removed at intervals and tested for firmness in order to obtain the required degree of fusion without solidification. The sintered glass circles are shaped on a sanding or emery wheel to fit into the slightly flared ends of 4½-inch sections of 10 millimeter outside diameter pyrex tubing. The plates are sealed in using a carbon rod to roll the softened glass onto the plate while rotating in a small gas-oxygen flame. It is advisable to place these sticks immediately in a warm muffle. The muffle temperature is raised to the annealing point (560 degrees C) and then allowed to cool overnight. See Kirk, Craig, and Rosenfels (4) for a more extended description.

Two automatic pipettes are constructed from standard three-way stopcocks. The smaller, holding roughly 0.2 milliliter, is constructed from a 1½ millimeter bore capillary pyrex stopcock (soft glass capillary tubing is more difficult to anneal). If the end of the common branch is heated centering on a point of such distance from the stopcock that the residual tubing will hold 0.2 milliliter, the volume contained after pulling off will be approximately correct. This point is easily ascertained by measurements on water delivered into the tubing with a 1 milliliter calibrated pipette. The point on the pipette should be pulled out long enough to reach to the bottom of the filter sticks and the tip should be not larger than 2 millimeters outside diameter. A second pipette of about 2-milliliter volume is similarly constructed of a three-way stopcock equipped with 8 millimeter outside diameter tubing for the branches. This pipette should be calibrated, utilizing a constant drainage time and the point should be lifted directly from the free liquid surface (an important point to be observed in carrying through the determinations). Under these conditions four such deliveries did not deviate more than 1 milligram from the average ($1.896 \pm .001$), indicating that the pipetting error should be negligible.

Both pipettes are filled by suction (filter pump) which is limited to 12 inches of water by use of a water-bottle trap. The remaining branch of the small pipette is connected to a distilled water supply so that the entire contents may be rinsed out. A preliminary test will indicate the washing time needed, although a moderately fine-pointed pipette washes out a strong dipicrylaminate solution in about 5 seconds so an allowance of 10 seconds is probably ample.

Procedure for Determination

Briefly the procedure depends upon the addition of excess lithium dipicrylaminate (saturated with the potassium salt) to the dried resi-

due of the potassium-containing sample. A filtered aliquot is taken to determine the residual dye colorimetrically.

Small aliquots of the samples to be analyzed are placed in the ½-inch test tubes, preferably by means of the calibrated 2-milliliter automatic pipette. Smaller or larger aliquots are taken, however, as required to place the quantity of potassium taken in the most favorable range for accuracy (approximately 0.4 to 1.2 milligram). Special automatic pipettes, such as those described, are very desirable for accurate delivery of small volumes. The solution contained in the test tubes is evaporated to dryness by placing in a ventilated oven at 130 degrees C overnight. The presence of relatively nonvolatile acids should be avoided. A glass bead is dropped in each test tube to serve as a grinding medium. After attaining room temperature, an aliquot of the lithium dipicrylaminate solution is added by means of the 2-milliliter automatic pipette, taking care that the solution is all placed in the bottom of the test tube. After shaking on the shaker for 15 minutes, which serves to grind up the crust of salts in the bottom of the test tubes and allows an equilibrium to be attained in the precipitation of potassium dipicrylaminate, a filter stick is placed in each test tube. The smaller automatic pipette is used to remove an aliquot of the filtrate from within the filter tube (sufficient solution is present to rinse the pipette thoroughly if properly handled). The aliquot is then washed out into a 100-milliliter volumetric flask and subsequently made to volume. The transmission is measured in a simplified photoelectric colorimeter constructed along the general principles of Evelyn's (2) design. Corning glass filters Nos. 430 and 503 are utilized.

Standard solutions of potassium chloride are utilized in this same way in order to draw a standardization curve, since this procedure tends to eliminate such errors as nonlinear galvanometer response, pipetting, and other technique-introduced variations.

Discussion

The filter sticks can be dispensed with by centrifuging and pipetting from the supernatant liquid. The results are only moderately satisfactory, however, as the precipitate tends to float and temperature control is uncertain. Amdur (1) utilized a piece of filter paper over the end of a blood pipette. His technique, however, is tedious and the filter paper absorbs a certain amount of the dipicrylaminate.

Since the potassium dipicrylaminate solubility varies considerably with changes in temperature, it is essential to control the laboratory temperature closely. Amdur (1) concludes ± 3 per cent deviation is allowable from the temperature at which the standard was run. It is possible to run standard samples with each lot of determinations if the temperature cannot be regulated sufficiently.

The pipette overflow from dye solutions as well as other residues may be saved and the dipicrylamine precipitated with a small quantity of hydrochloric acid. The resultant precipitate after filtering off and after washing with water is ready for re-use. Kolthoff and Bendix (5) caution that the reagent may produce unpleasant skin reactions so contact should be avoided.

The potassium contents of 50 ash solutions (from cane samples of *Vitis vinifera*, various varieties) were determined in duplicate by a chloroplatinate method (3) and by dipicrylamine. Both procedures were standardized against the same sample of pure KCl. The average for the chloroplatinate determinations was 0.527 per cent potassium while that for the dipicrylamine was 0.529 per cent. Table I indicates the greater reproducibility of the dipicrylamine determination.

TABLE I—VARIABILITY OF DUPLICATE DETERMINATIONS OF POTASSIUM

Percentage Deviation of the Duplicates From Their Mean Values	Number of Duplicates in the Given Range						
	0.05	0.51–1.0	1.1–2.0	2.1–3.0	3.1–4.0	4.1–5.0	5.1–
Chloroplatinate determinations	13	3	14	5	5	3	7
Dipicrylamine determinations	35	8	5	1	0	1	0

It should be pointed out that 150 determinations by the dipicrylamine procedure were carried out in somewhat less time than was required for 24 determinations by the chloroplatinate method.

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Manganese Deficiency in Citrus

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FOLLOWING the identification of symptoms of manganese deficiency on citrus trees in California, an extensive series of field experiments was inaugurated to determine the distribution of this deficiency, its manifestations, and the effects of treatment.[1]

Occurrence

Symptoms of manganese deficiency have been found in varying degrees of severity on citrus over a wide area in southern California. The symptoms have responded, at least superficially, to manganese treatment. In many areas the symptoms are mild and the obvious effects are slight. The most severe symptoms have been found on trees growing on Yolo and certain Hanford soils in coastal and intermediate areas (7). These soils are used extensively for citrus culture and are normally considered fertile. They are frequently somewhat calcareous in the seriously affected areas. Determinations upon samples of these soils taken from certain orchards where citrus shows severe deficiency symptoms indicate a pH range of 6.4 to 7.5 when the moisture content of the soil samples is adjusted to the "sticky point".[2] This reaction is not uncommonly alkaline, and some soils, on which manganese deficiency is mild or absent, are as calcareous.

Contrary to observations in Florida (1, 4), the areas in California in which symptoms of manganese deficiency have been observed on citrus are not those in which zinc deficiency is most serious. The latter deficiency is common throughout California but is more prevalent on soils in the interior citrus areas than on those near the coast. The reverse is true of manganese deficiency, symptoms of which are practically lacking in such interior areas as the San Joaquin and Moreno valleys but are prevalent in coastal areas. The effect of climate on the development of zinc deficiency symptoms has been found to be very important (5, 6); this is suggested by the fact that such symptoms are generally more severe on the south sides of trees than on the north. While symptoms of manganese deficiency are found on all sides of citrus trees, they are often most severe on the north exposure of the trees and frequently show most plainly on the last cycle of growth during the winter. This suggests that climate has an effect on the development of leaf symptoms of manganese deficiency, though this effect is not identical with that of climate upon zinc deficiency symptoms.

Severe leaf symptoms of manganese deficiency on citrus have in some cases been accompanied by mild or fleeting symptoms of iron chlorosis. Serious iron chlorosis obscures manganese deficiency symptoms. Manganese deficiency symptoms on citrus have been associated

[1]The coöperation of the Agricultural Extension Service and of more than one hundred growers is gratefully acknowledged.

[2]These analyses were made by [illegible].

with similar symptoms on walnuts, plums, peaches, and apricots, which have responded to spray treatment. In the few comparisons observed, Avocados, apples, and pears appear to be less likely to develop leaf symptoms under the same conditions. Deficiency symptoms have not been observed on truck crops in the areas in which citrus trees show distinct symptoms.

It is probable that manganese deficiency symptoms were formerly confused with symptoms of zinc and iron deficiencies (4), or were masked by them. However, there is some evidence which suggests that manganese symptoms are increasing in severity in many citrus orchards. The application of zinc in certain of these orchards a few years ago resulted in normal foliage. When mottling recurred further applications of zinc had little or no effect. Recent responses to manganese indicate, however, the development of marked manganese deficiency. This is due, possibly, to depletion of manganese as a result of tree growth, but it may also be due to effects of cultivation and irrigation upon manganese availability.

Methods of Treatment

Applications of large amounts of manganese sulfate to the soil about citrus trees were made in California by various workers as early as 1930, and sprays were applied at a somewhat later date without detectable result. It might be noted, however, that in one experiment, two trees which were treated in 1931 by G. Surr and L. D. Batchelor (unpublished) have now nearly normal foliage. Each of the four tree squares about one of these trees received 60 pounds of commercial manganese sulfate broadcast. Each square about the other tree received 80 pounds of material. Adjacent trees receiving 10 to 20 pounds per tree square now show symptoms of manganese deficiency. This difference was not observed 2 years ago. Other experiments with soil applications have not given suggestive responses, although the manganese sulfate has been applied in large quantities and in different ways. The soils on which these soil applications were made, like most citrus soils in California, have relatively high fixing powers. The results of experiments with many crops (3, 8) indicate that under such conditions soil applications of manganese are not efficient. The present results with citrus are in harmony with these conclusions.

Although recovery from deficiency symptoms has been secured by means of injection of crystals and solutions of manganese salts into the tree (7), foliage sprays have proved to be the most effective and practical method of correcting manganese deficiency symptoms of citrus in California. Applications of C. P. grade of $MnSO_4$, $MnCl_2$, $KMnO_4$, MnO, and MnO_2 in solution or in suspension have all resulted in satisfactory improvement of affected leaves. Commercial grades of 65 to 80 per cent manganese sulfate appear to be satisfactory, provided the impurities which they contain are either soluble or so finely divided that they do not interfere with spraying operations. In several experiments such materials have been applied throughout the year, alone and with precipitants, in various concentrations based on their manganese content.

Solutions of 10 pounds of manganese sulfate per 100 gallons of water (10–0–100) have occasionally caused burning of tender orange leaves and more serious burning of tender lemon leaves. Necrotic spots appeared first in the lower surfaces of the leaves and later penetrated through them. Precipitation of manganese in the spray by the addition of hydrated lime or soda ash in quantities equal to one half the weight of manganese sulfate used (i.e., 10–5–100) prevented this injury. Other symptoms of manganese toxicity, which will be described presently (see "Manganese Toxicity," p. 9), frequently developed on lemon leaves after solid injection or spraying with manganese solutions. Such symptoms failed to develop on grapefruit or orange leaves. Concentrated sprays caused more severe injury of this type than dilute sprays, but toxicity symptoms resulted from sprays as dilute as about 3–0–100. The addition of soda ash to the spray reduced the occurrence and severity of this toxicity symptom but did not entirely eliminate it until the spray concentration was reduced to less than 5–2.5–100.

The rate of improvement of deficient foliage and the duration of response have been used as criteria in studying the effectiveness of spray concentrations. It now appears that sprays containing about 3 pounds of manganese sulfate per 100 gallons of water caused practically as good leaf responses as more concentrated sprays. The addition of soda ash as a precipitant had little if any influence on the effectiveness of the treatment. Since the addition of soda ash made the manganese treatment safer, it appears advisable to use it. The formula 3–1.5–100 appears sufficiently concentrated for very good results and safe for the original treatment of lemon trees. As a precipitant with manganese sulfate, soda ash appears preferable to hydrated lime: its use does not result in such an objectionable deposit on leaves and fruits, and it is a more satisfactory spraying material.

As a result of trials in which sprays have been applied at various rates and concentrations, it has appeared that "skeleton" sprays are satisfactory, provided all leaves receive some spray. Leaves receiving no spray responded very slowly or not at all.

Sprays applied at all seasons of the year have been effective; but those applied just prior to the important spring and winter growth cycles have given rapid responses, while those applied after the fall growth cycle has been completed, or during the winter, have usually not resulted in foliage improvement until the spring growth occurred.

Combination sprays of manganese sulfate with copper or zinc sulfates have been used successfully where deficiencies of these elements exist. With these sprays a precipitant is necessary and must be used in quantity sufficient to combine with all the metallic salts.

Responses to Treatment

The time required for correction of foliage symptoms of manganese deficiency by use of sprays has appeared to bear an inverse relation to the age of the leaves. When treatment occurred during the summer months, leaves which were in an active state of growth at time of treatment often turned green in 10 to 15 days. Leaves which were two to three cycles old required a somewhat longer time. Very old leaves

of orange trees frequently required several months to a year or more before assuming a normal green color, and old lemon leaves which had become dull in color generally failed to improve at all.

It has also been observed that, except perhaps on growing leaves, trees sprayed in the winter time usually showed no decided improvement before the spring cycle of growth took place. The first few cycles of new growth which appeared after treatment were frequently normal in color. Very clear-cut mottling has recurred, however, on light green leaves of late fall and winter growth of oranges and grapefruit trees in the interior of California which were sprayed with manganese the previous June. This pattern frequently disappeared as these leaves hardened and became darker green with the advent of warm summer weather, and affected leaves also became uniformly dark green when the trees were given a second treatment with manganese spray.

The correction of leaf symptoms by spraying has not resulted in pronounced increase in growth of the trees. In fact, tree improvement has been very slow and has seemed to take place chiefly as a result of the longer retention of old leaves on the trees. This has appeared to be the case with orange and grapefruit trees which were so severely deficient that their leaves fell prematurely, thus causing an open appearance. In some instances the leaves of the first cycle of growth appearing after spraying, appeared to be larger on treated trees. Any effect of correction of symptoms on fruit yield and fruit quality appears also to be slow, and quantitative measurements have not yet been obtained.

The slow or doubtful responses of deficient citrus trees might be explained at this time by at least three theories: (a) that the quantity of manganese absorbed by the leaves to tissues where it may be required is insufficient or its movement is very slow; (b) that the effect of applied manganese is chiefly upon carbohydrate synthesis, and the effect of increased carbohydrate supply is slow to exhibit itself; or (c) that symptoms of manganese deficiency are accompanied by another more primary deleterious condition. In regard to the first of these hypotheses it might be mentioned that the injection of crystals of manganese sulfate and chloride and also of solutions of manganese sulfate into the tree trunks under pressure has to date had no more beneficial effect on the trees than has spraying.

Manganese Deficiency and Lemon Tree Decline

It appears that manganese deficiency in citrus is associated more with tree health than with yield. Many trees which show marked symptoms of manganese deficiency produce satisfactory crops. There is also evidence that manganese deficiency is associated with a certain type of lemon tree decline.

In some areas, especially on Yolo soil, lemon trees frequently decline rapidly at 10 to 20 years of age. Orange trees and young lemon trees in these areas show clear-cut symptoms of manganese deficiency, and the declining trees themselves show similar symptoms on young but mature leaves. The pattern usually fades out as the leaves age. The older leaves turn a dull yellowish-green or brassy color, drop pre-

maturely, and the declining tree assumes a very thin appearance.

The onset of decline is very rapid when it is preceded by a heavy set of fruit. In such cases the fruit colors prematurely on the trees and is often small sized and unmarketable as fresh fruit. A heavy leaf-fall occurs and ensuing new growth is weak and light green in color. Treatment of trees in the process of rapid decline with manganese sprays has been observed to clear up the typical deficiency symptoms on the young, mottled leaves, but the older bronzed leaves continued to fall and did not change color. Increased twig growth did not result. It appears that spraying does not immediately arrest the decline. It might be supposed that spraying does not supply sufficient manganese to all the tree in time to arrest decline, but trees injected with manganese sulfate in solution under pressure have to date reacted as have sprayed trees. It remains to be determined whether manganese treatment will have any influence on the prevention of decline.

MANGANESE TOXICITY

As previously stated, frequent burning of young leaves results from spraying with concentrated solutions of manganese sulfate or chloride. This injury, which has been more severe on lemons than on oranges, appeared soon after spraying. Necrotic spots, 1 to 4 millimeters in diameter, developed first on the under side of the leaves, and, in many cases, the necrosis subsequently extended through them. Abscission of the leaves was usually not immediate, and the fruit was not injured. This type of injury has been prevented by the use of a precipitant such as hydrated lime or soda ash with the manganese sulfate.

Additional leaf symptoms of manganese toxicity have been mentioned as caused by treatment of lemon trees, but not of orange or grapefruit trees. These symptoms have been developed by several procedures: by spraying with 50 to 100 grams per gallon of C.P. $MnCl_2$, by solid injection of crystals of this chemical, and by spraying with 5 or more pounds of C.P. or commercial spraying grades of manganese sulfate per 100 gallons of water. The severity of the toxicity symptoms was related to the amount or concentration of the manganese salt used and was reduced, but not eliminated, by inclusion in the sprays of a suitable precipitant, as mentioned above.

Manganese-deficient lemon leaves affected by these treatments first lost the mottled pattern of deficient leaves and after a considerable period of time developed bands of yellow color affecting all tissues along the margins of the leaves. These bands of yellow tissue were at first sharply delineated by an almost straight unbroken line from the green area of the leaf. In time, the line of contact of the yellow areas and the green tissues became less clearly defined, and the yellow areas extended into those interveinal areas which were at first green, while at the same time some of the veins which were in the yellow areas turned green (see Fig. 1). As the leaves became old, they became dull, and the pattern became more indefinite. In some cases the leaves looked a good deal like old decadent leaves on decline-type trees; in other cases they appeared like those showing certain symptoms of nitrogen or magnesium deficiency (2). The affected leaves did not

FIG. 1. Symptoms of manganese toxicity of lemon leaves. At the first indication of this symptom the yellow band along the margin is delineated from the green area of the leaf by an almost straight, unbroken line.

drop prematurely. Large young leaves were affected more severely than old leaves. Trees which had not shown vigorous growth for some time seemed to develop the symptoms less readily than vigorous trees. The symptoms were accentuated by repeated spraying.

This symptom has to date affected only the leaves which were on the trees at the time of treatment. New growth coming out above or below affected leaves has been normal. Since the symptoms are probably the result of excessive amounts of manganese in the leaves, the failure to affect adjacent younger leaves suggests that manganese is not very mobile in lemon tissues. This is suggested also in orange and grapefruit by the observation that new fall growth on recently sprayed trees is sometimes affected with deficiency symptoms.

The appearance of these toxicity symptoms has always been delayed in our trials. In some cases they developed several months after treatment. Trees sprayed or injected in the fall did not develop symptoms until the spring growth took place.

Manganese Treatment and Cyanide Fumigation

In two orchards in the coastal plain, about 10 miles apart, lemon trees which had been sprayed with manganese were seriously damaged by HCN fumigation. The injury occurred on the same nights in both orchards. The trees were seriously defoliated, and some twig injury resulted. The injured trees in one orchard had been sprayed 5 months previously, and in the other, 2.5 months previously. No new growth had occurred between time of spraying and fumigation. In one of these

orchards, certain other experimental trees which had been sprayed 7 months before fumigation and had improved in color and produced a new cycle of growth soon after spraying were not injured by fumigation at this time, nor were unsprayed check trees injured. Since the rows of one of the orchards were fumigated at hourly intervals on two nights, an examination of continuous temperature and humidity records was made. An apparent correlation between very high humidity and severity of damage resulted.

Attempts to duplicate these results at Riverside have been made by Dr. D. L. Lindgren in coöperation with the authors. Orange and lemon trees were sprayed August 19, 1940, with manganese sulfate and soda ash, 10–5–100 and 4–2–100. They were then repeatedly fumigated over an 8-month period at moderate and at high humidities. In no case did injury result. In a number of our field trials the trees were fumigated during the first night after they had been sprayed with manganese, without injury. The reasons for the occasional instances in which manganese treatment has increased injury due to subsequent fumigation are obscure but may be similar to those which are very occasionally reported when fumigation follows treatment of citrus trees with "safe" copper sprays. It appears advisable, however, to fumigate recently manganese-sprayed trees only when conditions are very favorable, and perhaps only after a growth cycle has occurred following the spray treatment.

Summary

Manganese deficiency symptoms on citrus were found to be widespread in California. Their distribution was found to differ from the distribution of zinc deficiency symptoms. Symptoms of manganese deficiency are generally mild and occur on trees which are highly productive as well as on decadent trees. Severe deficiency symptoms are in some areas associated with early decline of lemon trees. Although leaf symptoms of deficiency were eliminated by spraying with manganese mixtures, no obvious effect on tree health or yield resulted during two years of observation except in the case of very severely deficient orange and grapefruit trees the leaves of which had dropped prematurely. Suitable sprays were developed for treating manganese deficiency. Improper sprays were found to result in burning of young orange and lemon leaves, and to result in other symptoms of toxicity on lemon leaves which are described. Manganese sprays in two instances seriously increased injury due to subsequent fumigation with HCN, but these results could not be duplicated at will.

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Influence of Time of Harvest on Storage Scald Development of Rhode Island Greening and Cortland Apples

By E. P. CHRISTOPHER, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

ABSTRACT

To be published in full as a Circular for the Rhode Island Agricultural Experiment Station.

THREE years data on the development of scald both in storage and after removal from storage gave further evidence of the importance of delayed harvest in reducing the danger of this difficulty on Rhode Island Greening and Cortland apples.

With Greenings, some differences due to season and soil fertility conditions were noted while with Cortland, time of harvest was the only variable factor involved. Apparently any beneficial effects from delayed harvest are more pronounced during the early part of the storage season.

Under the conditions of these tests, delaying harvest of Greenings to late September resulted in greater size, less scald and very little breakdown. Cortland harvested up to mid-October improved in size, color, and freedom from scald both in storage and after removal to room temperature.

An Evaluation of Some of the Factors Affecting Quality of Grapefruit in Commercial Groves of the Salt River Valley[1]

By WILLIAM E. MARTIN, *University of Arizona, Tucson, Ariz.*

MUCH variation has been seen in grapefruit produced in different groves in the Salt River Valley of Arizona. In some years the general quality is better than in others. Some districts commonly produce superior fruit but differences in quality occur within a district or even between adjacent groves. In fact, the extremes of high and low quality may occur in closely adjoining groves within any district.

Quality, as considered here, refers to the comparative marketability of the fruit and may be judged by the relative proportion of high-grade fruit to low-grade or cull fruit marketable only as by-products. High-quality fruit is characterized by a smooth external texture, regular slightly oblate form, medium size, and relatively thin skin; while low quality fruit is characterized by coarse skin texture, irregular form, tending toward large undesirable sizes with extremely thick skin. From the practical aspect the most satisfactory measure of quality is what the fruit will return when graded and marketed through a commercial packing house. In this report, therefore, the quality measure used is the price paid to the grower per field box after deducting all costs of harvesting, packing, and selling.

It has been evident that many growers who thought they were taking the best of care of their groves were not necessarily the ones receiving the highest returns, and in many cases the neglected groves were the ones producing the highest quality fruit although often with rather low yields. Returns to members of the Arizona Citrus Growers during the 1939–40 season varied from 7.7 cents to 18.8 cents per box and from $2.77 to $136.37 per acre.

This study was undertaken during the past winter to attempt to evaluate and identify the factors responsible for the observed variations in quality and returns and to determine from practical material the most efficient methods of handling grapefruit groves, that is those methods which provide maximum production and at the same time high quality fruit. The data here presented are for the 1939–40 season. Further data are being gathered for subsequent seasons.

METHODS AND MATERIALS

A general study of commercial groves belonging to the members of the Arizona Citrus Growers has been made and detail records of cultural operations and other features of 90 of these groves have been obtained. These records include water usage, winter and summer cover crop practices, fertilization, and soil type.

Full access to the records of the Arizona Citrus Growers was available and records for a total of 266 groves were obtained. The records

[1]The writer wishes to acknowledge the complete and helpful cooperation of the management of the growers of the Arizona Citrus Growers for their assistance in furnishing information for this report.

include production, quality, returns per acre, and age of tree; as well as other information regarding cultural operations and past history of the groves. Data on yield and quality were made in all cases from careful sample pickings carried out for the expressed purpose of determining quality and production for participation in the seasonal pool. Table I may be helpful in interpreting the quality data in terms of the usual commercial grades.

TABLE I—RELATION OF COMMERCIAL GRADE TO PRICE

Commercial Grade	Approximate Price/ Field Box (Cents)	Range (Cents)
No. 1—Fancy	18.56	10.87—21.56
No. 2—Choice	10.88	6.38—13.87
No. 3—Standard	5.63	None
No. 4—Culls	3.75	None

PRESENTATION OF DATA

A. EFFECTS OF PRODUCTION AND AGE OF TREE ON QUALITY

Relation of Production to Quality:—It has been noted in the field and reported from this station (3) that quality appears to be associated with production. Years of large crops are years of good quality and years of light crop are years of relatively poor quality generally. In any year it appears that trees with heavy production tend to produce better fruit than trees bearing a light crop.

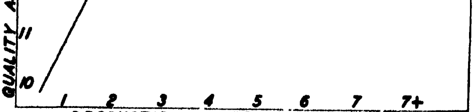

FIG. 1. Effect of production on quality.

Data showing the relation between production and quality are shown in Fig. 1 and Table III. These data, derived from 252 groves, show that quality increases rapidly as production increases to about four boxes per tree and that with further increases in production there is no further gain in quality.

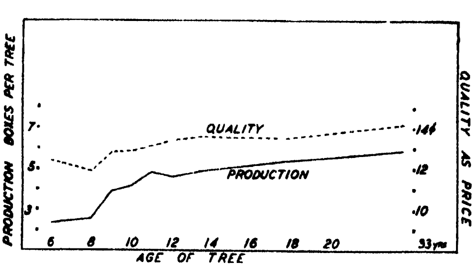

FIG. 2. Effect of age of tree on production and quality.

Relation of Age of Tree to Quality:—It has been thought that age of tree is apparently a factor. Data showing this relationship in 250 groves are shown in Fig. 2 and Table II. It may be seen that slightly better fruit was found on older trees than on younger trees.

TABLE II—EFFECT OF AGE OF TREE ON PRODUCTION AND QUALITY (1939–40 SEASON)

Age Group (Years)	Production				Quality	
	Number of Groves	Range in Production Low	Range in Production High	Average Production (Boxes)	Number of Groves	Average (Cents)
5 to 7	4	.59	3.50	2.29	4	12.40
8	15	.40	5.24	2.51	14	11.94
9	24	1.40	7.62	3.93	24	12.83
10	49	.90	8.35	4.15	47	12.96
11	29	.80	9.50	4.86	28	12.57
12	53	1.33	8.22	4.61	51	13.36
13 to 14	37	1.76	9.15	4.93	37	13.56
15 to 20	29	2.29	10.56	5.32	29	13.48
21 to 33	21	2.51	12.75	5.91	16	14.16

Relative Effects of Production and Age of Tree on Quality:—The questions may well be asked: "Do older trees bear better fruit because they have more fruit on the tree or because they are older?" And also "Is production a factor affecting quality or do we merely find more fruit on older trees?"

It is to be expected that production should increase with age. This relationship as determined from 261 groves for the 1939–40 season is shown in Fig. 2 and Table II.

It will be noted that the curves for yield and quality in Fig. 2 are similar but not identical, and it may be seen from Table II that there is a very large variation in production in any age group. Similar variation in quality exists.

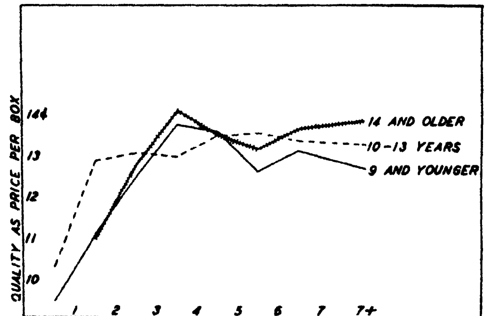

FIG. 3. Effect of production on quality of fruit from trees of three age groups.

By considering trees of a single age only in relation to quality it should be possible to evaluate the effects of production upon quality independent of age. This was done by segregating all groves into three groups: 5 to 9 years, 10 to 13 years, and 14 years and older. The data from each age group were handled separately and production plotted against quality in each case as shown in Fig. 3 and Table III. It will be noted that regardless of age of tree the same type of curve is obtained. It appears, however, that with low production both young and old groves may have slightly poorer quality than groves of medium age, while at production above six boxes per tree quality appears to increase slightly with age of tree.

It seems evident that the effect of age tree on quality is minor and that the number of fruit on the tree is of much more importance in affecting quality.

TABLE III—EFFECTS OF AGE OF TREE AND PRODUCTION UPON QUALITY (1939–40 SEASON, SALT RIVER VALLEY)

Production (Boxes/Tree)	Quality of Each Age Group* 5 to 9 Years (Cents)	10 to 13 Years (Cents)	14 to 34 Years (Cents)	Average Quality (Cents)	Number Groves
Under 1	9 47	10 30	——	9.80	5
1 to 2	11 10	12.91	11 00	11.84	18
2 to 3	12 48	13 09	12.80	12.85	25
3 to 4	13.78	13.01	14.10	13.28	49
4 to 5	13.60	13 50	13 55	13 52	56
5 to 6	12 64	13.60	13.18	13 35	52
6 to 7	13.13	13 40	13 69	13.46	30
Over 7	12.70	13.33	13 91	13 56	17
Average	12.25	13.27	13.53	13 17	
Number of groves	40	148	64	Total number of groves	252
Average production	3.28	4.52	5.47		

*Expressed as price per box.

B. FACTORS AFFECTING PRODUCTION

Nitrogen Application:—Orchard management data were gathered from 83 groves of which only 33 had received nitrogenous fertilizers. Manure, calcium nitrate, and ammonium sulphate were the only materials reported. The quality, actual production, and relative production from each treatment are listed in Table IV. By relative production is

TABLE IV—EFFECT OF N APPLICATION ON YIELD AND QUALITY

Treatment	Number of Groves	Production (Boxes)	Relative Production (Per Cent)	Quality* (Cents)	Average Amount Applied
Manure	14	6 31	136 1	13.15	6 5 Tons/acre
Calcium nitrate	11	6.39	127 8	13.05	3.9 Pounds/tree
Ammonium sulphate	8	5.19	110.8	12.69	4.4 Pounds/tree
Average of N added. .	33	6.07	127.2	13.01	
None	83	4.46	103 1	13.07	

*Price per field box.

meant the percentage that the observed production is of the average production of all groves of the same age. Nitrogen application as a whole increased relative production about 23 per cent and actual production 36 per cent with no apparent change in quality. Manure and calcium nitrate appeared superior to ammonium sulphate in the amounts supplied and in the limited number of groves observed.

It is quite in line with observations in the field and published reports from this station (1) that nitrogen, in spite of wide variation in form and time of application, gives response in increasing yields. The efficiency of manure has long been recognized by growers in the Salt River Valley although it has proved less satisfactory on the light sands of the University of Arizona Experimental Farm at Yuma.

Winter Cover Crops:—Winter cover crops are commonly grown in the winter months and are made up principally of sour clover (*Melilotus indica*), malva (*Malva parviflora*), and wild oats (Avena sp.). Of the 83 groves reported in Table V, 25 were kept clean in the

winter months, 14 had non-leguminous weeds (malva and oats) while 44 had cover crops of sour clover alone or with non-leguminous weeds. In relative production those in clean culture were highest, those with non-leguminous weeds next, and those with sour clover the lowest.

Winter Cover Crops and Nitrogen Application.—The inter-relation of the effects of winter cover crops and nitrogenous fertilizers upon production is also shown in Table V. It appears that if nitrogen is not

TABLE V—EFFECTS OF WINTER COVER CROPS AND NITROGEN ON PRODUCTION

Cover Crop	Fertilization	Number of Groves	Production (Boxes)	Relative Production (Per Cent)
Clean culture	None	15	4.30	105.7
	Nitrogen	10	6.42	138.9
	All	25	5.15	119.0
Non-leguminous weeds	None	8	4 62	104.9
	Nitrogen	6	6 67	125.5
	All	14	5.50	113.8
Sour clover ±weeds	None	27	4.43	101.2
	Nitrogen	17	5.69	115.4
	All	44	4.92	106 7

applied, sour clover gives the lowest relative yield, with non-leguminous weeds next largest and with clean culture the highest relative production. The same relationship was observed where nitrogen was applied. From these limited data it appears that sour clover may not be as desirable a winter cover crop as has been popularly supposed.

C. RELATION OF SUMMER COVER CROPS TO QUALITY

As already pointed out, groves not receiving what has been commonly considered to be the best of care have in many cases been the ones producing the highest quality fruit. Summer weeds, if given opportunity, grow luxuriantly and include Careless weed (*Amaranthus Palmeri*) which is found in most groves, and Johnson grass and Bermuda grass which occur in the most neglected groves. The relation between quality and summer cover crops in 92 groves is shown in Table VI. The quality was poorest in the clean cultivated groves, somewhat better with the Careless weed and Johnson grass, and by far the highest where the Bermuda grass was present.

In all groups, except the Bermuda, some groves were fertilized during the fall, winter, or spring and considerably higher actual production was noted than in corresponding unfertilized groves. It may be seen from Table VI that the unfertilized groves of all groups have about the same actual production but with lesser relative production in the Johnson and Bermuda grass groves than in the other two groups. Quality was not appreciably affected by nitrogen application applied. These data agree with previous observations from this station (4) that the growth of competing cover crops during the summer tends to improve quality. The data obtained for this report from growers gave no measure of the density of any of the cover crops. This fact adds to

the significance of the observation that summer cover crops as a whole still showed a clean cut effect upon quality.

TABLE VI—EFFECTS OF SUMMER COVER CROPS ON QUALITY AND PRODUCTION

Summer Cover Crop	Winter Fertilizer Application	Number of Groves	Quality* (Cents)	Actual Production (Boxes)	Relative Production (Per Cent)
Clean culture...........	N	7	12.77	6.25	135.7
	None	13	12.20	4.60	104.8
	All	20	12.40	5.18	115.7
Careless weed...........	N	18	13.02	5.82	124.3
	None	45	13.43	4.62	105.6
	All	63	13.31	4.96	110.2
Johnson grass...........	N	2	14.35	5.78	114.5
	None	12	13.22	4.45	92.4
	All	14	13.38	4.64	95.6
Bermuda...............	None	8	14.54	4.07	95.6

*Price per field box.

D. Relation of Soil Type to Quality

The citrus groves in the Salt River Valley are grown upon three principal soil types: the Cajon loams, the McClellan loams, and the Mojave loams. A large proportion of the Mojave loams which are planted to grapefruit are highly calcareous gravelly, sandy types while the McClellan and Cajon loams are somewhat heavier and contain much less lime (2). The quality of fruit found in groves on these three soil types is shown in Table VII.

TABLE VII—EFFECT OF SOIL TYPE AND SUMMER COVER CROP ON QUALITY

Soil	Number of Groves	Quality* (Cents)	Clean Culture		Summer Weeds	
			No.	Quality (Cents)	No.	Quality (Cents)
Mojave................	76	12.87	6	12.80	22	12.95
McClellan.............	20	13.24	1	10.90	7	13.83
Cajon.................	75	13.64	9	12.84	26	13.98

*Price per field box.

The differences in quality between soils are slight and do not appear to bear out the local reputation of the Mojave soils for causing much poorer fruit than found on the somewhat heavier soils of the other two series. On each soil type slightly better fruit was obtained where summer weeds were grown than under clean culture.

E. Relation of Amount of Irrigation Water to Quality

It has been popularly supposed that groves short of water tend to produce poorer quality fruit than groves well irrigated. In Table VIII are shown the relative effects on quality of different amounts of irrigation water annually.

The groves receiving less than 3 acre feet per acre during the 1939 season produced somewhat coarser fruit than groves receiving more water, with quality increasing as the amount of water was increased. This agrees with the results of experiments carried out at the Yuma

TABLE VIII—EFFECT OF AMOUNT OF IRRIGATION WATER ON QUALITY

Amount of Water (Acre Feet Per Acre)	Number of Groves	Quality (Cents)
Less than 3	23	12.34
3 to 4	34	13.35
4 to 5	15	13.71
Over 5	4	13.98

Mesa Experimental Station during the last season which have shown a marked reduction in quality in plots receiving much less than the usual irrigation.

F. EVALUATION OF FACTORS AFFECTING QUALITY

It has been pointed out in the preceding sections that production, soil type, summer cover crops, and water supply all appear to have small effects upon the quality of the fruit produced. There are undoubtedly other factors. Individually the effect of any single factor is small but together their effect may be considerable. A summary of the effects of production, summer cover crops, and water supply upon quality is shown in Table IX.

TABLE IX—COMBINED EFFECTS OF PRODUCTION, SUMMER CULTURE, AND WATER SUPPLY UPON QUALITY IN 76 GROVES IN THE SALT RIVER VALLEY

			Water Supply	Average Quality	Variation in Quality
Average Quality 13.23c	Low* Production 12.92c	Clean 10.73c	Low**	10.90	———
			High**	10.70	9.8–11.2
		Weeds 12.91c	Low	12.14	9.1–15.9
			High	13.30	9.4–17.6
	High* Production 13.59c	Clean 13.20c	Low	12.96	11.4–13.5
			High	13.35	11.8–16.7
		Weeds 13.71c	Low	13.03	11.7–14.4
			High	13.93	11.0–16.5

*Production: Low—Under 4 Boxes/Tree; High—Over 4 Boxes/Tree.
**Water Supply: Low—Under 3 acre feet; High—3 acre feet and over.

The data of this table are taken from 76 groves where complete management records were available and illustrate the combined effects of the three factors under consideration. The quality differences due to any single factor are slight. However, a comparison of the groves of low production, clean culture, and inadequate water with groves of high production, summer weed cover crops, and sufficient water show clear cut differences in quality. Even after evaluating the combined effects of the three factors considerable variation still remains as is

shown in the last column of Table IX. This suggests strongly that other factors are operative which may be fully as great in their effect as any of those that have been considered.

Summary

A study of a number of commercial groves has been made and the effects of a number of cultural and environmental factors upon quality have been observed. In spite of variations in form of nitrogen, time of application, and amount applied, the use of nitrogenous fertilizers was observed to result in increased production as compared to unfertilized groves as a whole. The use of winter cover crops does not appear significantly beneficial according to the data presented here. Some evidence was obtained indicating that winter cover crops may interfere to some extent with the uptake of nitrogen by the trees at a time when it is needed to insure production.

The following factors appear to influence quality:

Production:—As yields increase up to about four boxes per tree quality improves. Further increase in production has no apparent effect upon quality.

Summer Cover Crops:—Make for somewhat better quality fruit than does clean culture in the summer.

Water Supply:—Of less than 3 acre-feet per acre makes for somewhat poorer quality than is observed with larger applications of water.

Individual Effects:—Of the factors above upon quality are slight but in the aggregate their effects may be considerable and explain some, but not all, of the observed variation in fruit quality.

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Effect of Severity of Pruning on Top Regeneration in Citrus Trees

By S. H. CAMERON and R. W. HODGSON, *University of California, Los Angeles, Calif.*

EXTENSIVE studies of the effects of pruning evergreen fruit trees were begun at this station in the spring of 1938. Thus far the greater part of the work has been with citrus trees, mainly the Valencia orange. Investigations now in progress involve studies of the rate of top regeneration as influenced by (a) restriction of the number of new shoots, (b) time of pruning, and (c) severity of pruning, supplemented with laboratory analyses to determine the effect of pruning on the composition of both the old and new parts of the tree. The present paper constitutes a report on the effect of severity of pruning on the rate of top regeneration in two varieties of orange and one each of lemon and grapefruit.

METHODS AND MATERIALS

For determination of the growth response in these studies a uniform procedure has been consistently employed. At predetermined intervals after pruning, the trees were dug, subdivided into approximately 30 arbitrarily chosen fractions and subfractions, aliquots of which were preserved for subsequent chemical, microchemical and morphological determinations. Records of fresh and dry weights of all parts, number of leaves, and number and length of new shoots, where feasible, were kept. These records provide the data necessary for calculations of the rate of top regeneration and give some indication of the character of the new growth.

During the first 18 months of the studies as much as possible of the root system of every tree excavated was recovered by carefully raking over all the soil removed — some 50 to 60 tons. Calculations of the percentage composition of the root systems of 60 Valencia orange trees subdivided on the basis of diameter indicated that, if all roots more than 0.8 centimeter in diameter were recovered, calculated values for fresh weight could safely be assigned to roots of smaller diameter. Consequently after the first 18-month period the pruned trees were removed by a "short-cut" method which requires less than half as much time as complete excavation. All check trees were, however, completely excavated and in all cases samples of the small roots were saved for analysis.

The trees which furnished the data for this paper were 10 years old when they were differentially pruned in February, 1939. They were all grown on sweet orange seedling stocks, the seeds for which all came from the same parent tree. The seedlings were rigidly culled in an effort to eliminate all except those from nucellar embryos. The buds for each scion variety were all from the same parent tree.

Three degrees of severity of pruning were employed as follows:

A. Light, which involved the removal of all parts less than one centimeter in diameter and some thinning of the smaller branches. It was in

effect a skeletonizing treatment (Fig. 1, A). The prunings removed, including the leaves, comprised slightly more than a third of the total fresh weight of the tree, or approximately 45 per cent of the weight of top.

B. Medium, which consisted of the removal of everything except ten

FIG. 1. The types of pruning employed: A, light; B, medium; and C, heavy.

TABLE I—EFFECTS OF THREE DEGREES OF SEVERITY OF PRUNING ON THE RATE OF REGENERATION OF NEW TOP OF 10-YEAR OLD TREES OF VALENCIA AND WASHINGTON NAVEL ORANGE, MARSH GRAPEFRUIT AND EUREKA LEMON
(WEIGHTS EXCEPT YIELDS IN GRAMS)

		Tree			Prunings		New Top					Leaves			Crop (Pounds)	
		Weight Before Pruning						Per Cent of				Per Cent of Total				
	Year	Total	Above Ground	Branches	Weight	Per Cent of Total (1)*	Weight	Total (1)*	Above Ground (2)*	Branches (3)*	Prunings (4)*	Pruned Trees	Check Trees	Shoot Leaf Ratio as Per Cent	Pruned Trees	Check Trees
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Light								
Valencia	1	191243	157343	141923	84823	44	55460	29	36	39	65	23	21	24	—	—
	2	247339	206199	184679	100699	41	88451	36	43	48	88	22	—	62	123.0	277.0
Grapefruit	1	247592	193355	173595	77112	31	64020	26	33	37	83	19	19	33	—	—
	2	243682	192186	169726	77566	32	82156	34	43	48	105	19	—	80	238.0	246.5
Navel	1	156246	131386	120466	66226	42	43552	28	33	36	66	21	23	33	—	—
	2	171308	141768	129188	70308	41	59200	34	42	46	84	23	—	51	367.0	350.0
Lemon	1	150794	127114	115454	58514	39	42040	28	33	36	72	15	16	88	—	—
	2	176137	157157	139717	62597	36	41180	23	26	29	66	5	—	366	165.3	—
								Medium								
Valencia	1	212712	172962	154372	122472	58	31413	15	18	20	26	10	—	44	—	—
	2	217396	176296	153916	117936	54	69200	32	39	45	59	17	—	84	4.0	—
Grapefruit	1	170454	138174	125054	92534	54	32736	19	24	26	35	12	—	54	—	—
	2	208532	165532	146572	99792	48	80220	38	48	55	80	19	—	104	160.0	—
Navel	1	152752	125302	113632	88452	58	29065	19	23	26	33	14	—	41	—	—
Lemon	1	138668	118668	106468	81648	59	27149	20	23	25	33	11	—	71	—	—
	2	138132	120752	107792	77112	56	48840	35	40	45	63	11	—	223	108.3	—
								Heavy								
Valencia	1	198004	162824	146244	131544	66	22330	11	14	15	17	8	—	44	—	—
	2	209360	171937	154237	130637	62	56820	27	33	37	43	14	—	92	1.0	—
Grapefruit	1	202858	164598	151098	131998	65	28239	14	17	19	21	9	—	57	—	—
	2	217877	176017	155477	130637	60	72940	33	41	47	56	16	—	105	25.0	—
Navel	1	171969	148209	138109	123669	72	17831	10	12	13	14	7	—	49	—	—
	2	124412	102332	95532	88452	71	26200	21	26	27	30	12	—	79	77.0	—
Lemon	1	138788	120618	111228	99338	72	18128	13	15	16	18	7	—	86	—	—
	2	133420	119960	108840	95340	71	49600	37	41	45	52	13	—	185	125.4	—

*Refers to column number.

main or secondary scaffold branches approximately 3 feet long (Fig. 1, B). This treatment involved removal of slightly more than half the total fresh weight of the tree, or approximately 65 per cent of the weight of top.

C. Heavy, which left only five main scaffold branches about 18 inches in length (Fig. 1, C). The prunings in this treatment represented approximately two-thirds of the total fresh weight of the tree, or about 80 per cent of the weight of top.

It is evident that the heavy and medium treatments were closer together, as regards severity, than were the medium and light treatments. The prunings treatments were purposely all much more severe than commercial practice in order to accentuate, and render measurable, differences both in growth response and composition.

Excepting the navel orange, of which only one tree received medium pruning, there were two trees of each variety in each pruning treatment. The trees were permitted to regenerate tops without any restriction in the number of new shoots.

One year after pruning half the pruned trees together with suitable check trees were dug by the "short-cut" method and fractioned as described above. A year later the remaining trees were removed and handled in the same manner.

Data and Results

All the essential data relating to fresh weights of the 23 trees are presented in Table I. Values indicating the rate of regeneration in terms of (a) the original fresh weight of the tree, which was obtained by adding the weight of the prunings to the weight of the original parts of the tree when dug, (b) the weight of the above ground parts before pruning, (c) the weight of the branches and leaves, and (d) the weight of the prunings, are presented in columns 7, 8, 9, and 10, respectively. Apparently where tree growth is as uniform as it was in this case, the response to pruning treatments is equally as well shown, whether the amount of regeneration is calculated in relation to the total weight of the tree including the leaves, the above ground portions, or the branches and leaves only. These ratios show that the rate of recovery was inversely proportional to the severity of pruning and that relatively a much greater recovery was made the first year by the lightly pruned trees than by those heavily pruned. In fact calculated on any of these bases the lightly pruned trees produced two-thirds as much new growth the first year after pruning as they did in two years, whereas the medium pruned trees produced about an equal amount each year and the heavily pruned trees more than half of the total during the second year. Presumably this relationship would continue to obtain until full recovery had occurred in all treatments.

Perhaps the relationship between the weight of new top and the weight of prunings is the most satisfactory measure of the rate of regeneration. The values in column 10 represent new top growth calculated as a percentage of the weight of the prunings. They indicate a recovery of from 65 to 83 per cent during the first year and from 84 to 105 per cent during the two year period for the lightly pruned

trees. Corresponding values for the heavily pruned trees are 14 to 18 per cent during the first year and from 30 to 56 per cent during the two years. Values for the moderately pruned trees are intermediate in all cases.

That the lightly pruned trees more rapidly re-establish a normal complement of leaves than do the moderately and heavily pruned trees is indicated by the data presented in column 11. These values represent the relationship of the weight of new leaves to the original total weight of the tree before pruning, including leaves. In column 12 are presented data showing the percentage weight of leaves on check trees calculated on the same basis. Inspection of the values in these columns show that the lightly pruned trees by the end of the first year (probably earlier) had produced leaves equal in weight to those removed by the original pruning, and that there was no appreciable increase in leaf weight the second season. In the case of the lemon there was an apparent decrease, which however was due to almost complete defoliation of this tree just prior to digging. The moderately pruned trees during the first year produced slightly less than two-thirds of a normal quantity of leaves. During the second year they developed nearly a full complement. The heavily pruned trees had, at the end of the first year, produced slightly more than one-third of the normal weight of leaves and, excepting the grapefruit, had only about two-thirds the normal amount at the end of the second year.

It was not feasible to count and measure all the new shoots on these trees, which would have made possible direct comparisons of shoot size and weight in the different treatments. It can be stated categorically however that the more severe the pruning the larger were the individual shoots and leaves, although the differences were not great as between the heavily pruned and moderately pruned trees. Data which substantiate this statement are presented in column 13. These values represent the relationship between the weight of new shoots and new leaves. They indicate a lower shoot-leaf ratio on the lightly pruned than on the moderately and heavily pruned trees. Furthermore they show an appreciable increase the second year in all cases. The abnormally high values for the lemon tree the second year are due to the very heavy leaf drop referred to above. Since, in the case of the lightly pruned trees, the weight of leaves did not increase the second year whereas the leaf-shoot ratio did, most of the growth during this season must have been due to an increase in size of shoots.

Field notes show that resumption of blossoming occurred first in the lightly pruned trees and last in the heavily pruned trees and that the amount of bloom the year after pruning was roughly inversely proportional to the severity of pruning. Varietal and specific differences were also evident, the lemon being the first to resume blossoming followed by the navel orange, the grapefruit and Valencia orange.

All the pruned trees produced some fruit the second year after pruning. The amount of crop was inversely proportional to the severity of pruning with one exception; the heavily pruned lemon tree produced a somewhat larger crop than the moderately pruned tree. The lightly prunel navel and grapefruit trees produced crops as large as did the

control trees. The Valencia produced only about half as much as the control. The smaller crops of both pruned and control trees of the grapefruit and Valencia orange, as compared with the navel, are in considerable measure due to the fact that of necessity they were harvested some months before horticultural maturity had been attained. In the case of the lemon trees, the crops recorded represent what fruit was on the trees at the time they were dug. The production of both the light and medium pruned trees was actually considerably larger because of crops harvested prior to the time of digging and unfortunately not recorded.

Summary and Conclusions

A study of the rate of top regeneration following light, medium and heavy pruning of 23 ten-year-old citrus trees, representing two varieties of orange and one each of grapefruit and lemon, seems to justify the following conclusions:

1. That rate of top regeneration and resumption of fruiting during the first two years is inversely proportioned to the severity of pruning. Lightly pruned trees make more new growth the first year than they do the second, but severely pruned trees make more new growth the second year than they do the first.

2. That lightly pruned trees re-establish a full complement of leaves during the first year after pruning, but that heavily pruned trees require two or more years to produce leaves equal in weight to those removed by the pruning.

3. That under conditions where tree growth is uniform, an equally accurate calculation of the rate of top regeneration can be made on the basis of fresh weight of the above ground parts of the tree, or of the branches and leaves only, as upon the total weight of the tree.

Moisture Studies under Citrus using Tensiometers[1]

By L. A. Richards, *U. S. Regional Salinity Laboratory, Riverside, Calif.*, and M. R. Huberty, *University of California, Los Angeles, Calif.*

A YEAR'S record has been obtained on soil moisture tensiometers at eight depths down to 15 feet under each of two 11-year-old navel orange trees budded on sweet stock, one being irrigated twice as often as the other. The trees were located in field S3 Block Y of the University of California Citrus Experiment Station at Riverside. Irrigation water was applied in a level basin to a depth of 4 inches for each tree at each irrigation. During the irrigation season, tree 3 in row 16 received water every 4 weeks while tree 5 in row 14 received water every 2 weeks. The tensiometers were installed 6 inches apart in a line on the north side of the trees just under the outermost extension of the branches and about midway between the tree trunk and the basin border. The porous tensiometer cups were attached to steel tubes having lengths of 1, 2, 3, 4, 6, 8, 10, and 15 feet and the tops of the steel tubes were set 6 inches above the soil surface.[2] The actual depth of the porous cup in the soil was therefore 4¾ inches less than the corresponding steel tube length. For convenience in the following discussion, the various cups will be referred to by their steel tube lengths.

The trees were located in Ramona sandy loam which is permeable and well drained and the basins were kept weed free with a minimum of hand cultivation. An indication of soil texture is given by the curves inset in Fig. 4. The soil removed from the 15-foot tensiometer holes was composited in 1 foot intervals below the 6-inch depth and the amount of moisture these samples retained at a soil moisture tension of ½ atmosphere (38 centimeters of mercury) is shown plotted against depth. These values approximate the moisture equivalent. The installation of six units under each tree was completed on September 9, 1939. The 10-foot units were added on October 6, and the 15-foot units on November 17. The data shown in the accompanying figures are for the fall of 1939 and spring and summer of 1940.

The curves in Fig. 1 were plotted from daily manometer readings taken between 8 and 9 o'clock in the morning and show the changes occuring in the soil moisture tension at the various depths under the two trees during the fall of 1939. Attention is called to the fact that the vertical scale for the figure is broken into three different sections. The time of irrigation is indicated by tension drops, the wider and more immediate excursions occuring at the shallower depths. The tension

[1]Joint contribution from the U. S. Regional Salinity Laboratory, Bureau of Plant Industry, and the University of California.

The authors are indebted to William Taggart and William Picker for assistance with installing the tensiometers and taking the readings.

[2]The design of tensiometer used was substantially the same as that described by Richards, Russell, and Neal (2). Spout top porous cups were mounted on steel tubing for convenience in inserting the cup in a King tube hole in the soil. A manuscript entitled "Soil-moisture tensiometer materials and construction" has been prepared for publication and describes instruments now in use at the United States Regional Salinity Laboratory.

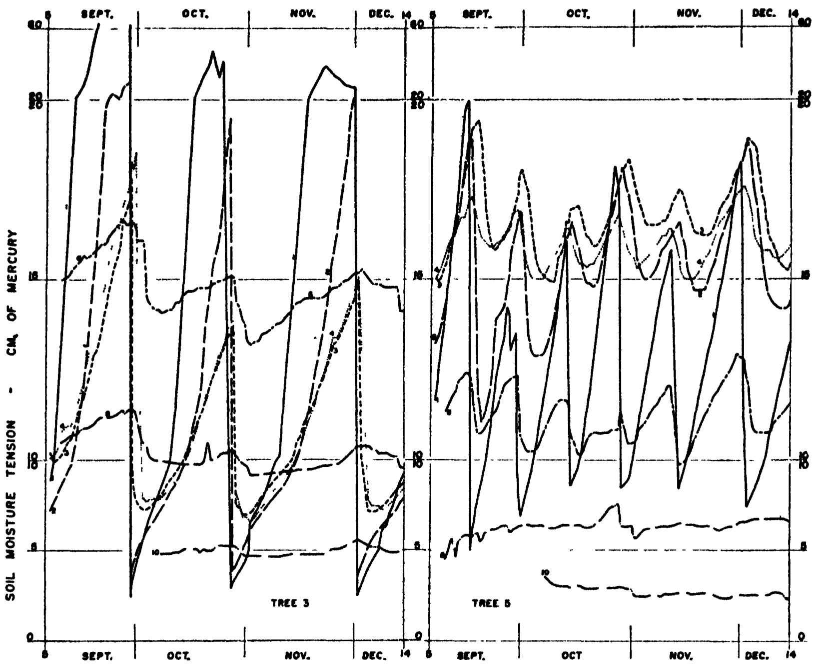

FIG. 1. Soil moisture tensions at eight depths under 11-year-old navel orange trees. An irrigation of 4 surface inches was applied every 4 weeks for tree 3 and every 2 weeks for tree 5.

minima for the 1- and 2-foot units were lower under tree 3 than under tree 5, which was irrigated twice as often. This apparent anomaly is due to reduced permeability of the surface soil under tree 5 caused by surface applications of ammonium sulfate (1). Even though water stood in the basin for many hours after irrigation the reduced infiltration rate coupled with a ready movement of water to lower soil layers did not permit the accumulation of enough water in the soil at the 1- and 2-foot cups to reduce the tension below 5 centimeters and 11 centimeters of mercury respectively. The all year tension minima measured in the soil layer between the 1- and 8-foot cups was 2.5 centimeters of mercury under tree 3 and 5 centimeters of mercury under tree 5. This indicates definitely that the irrigation did not produce saturation or a perched water table and that soil pores having equivalent diameters larger than 0.1 millimeter for tree 3 and 0.05 millimeter for tree 5 did not fill with water. It is concluded, therefore, that larger soil channels originating from worms, roots or cracks were not factors in conducting water in this soil layer. Only at soil depths below 6 feet was the soil moisture tension consistently lower under the tree with the frequent irrigation and this in spite of the fine textured soil layer occuring at 4.5 feet under tree 5.

The rate of moisture extraction by roots at the various soil depths is indicated by the rate of tension increase. The 1-foot unit under tree

3 gave readings above 60 centimeters during the latter part of September and had to be refilled at the time of irrigation. The moisture extraction rate by the roots was about the same at the 4- and 3-foot depths and was increasingly higher at the 2- and the 1-foot depths. It would seem from the fluctuation in the curves that there was appreciable moisture extraction between irrigations at the 6- and to a lesser extent under tree 3 at the 8- and 10-foot depths also.

The curves in Fig. 2 show the negative pressure of the water in the tensiometer systems at the level of the soil surface instead of the tension

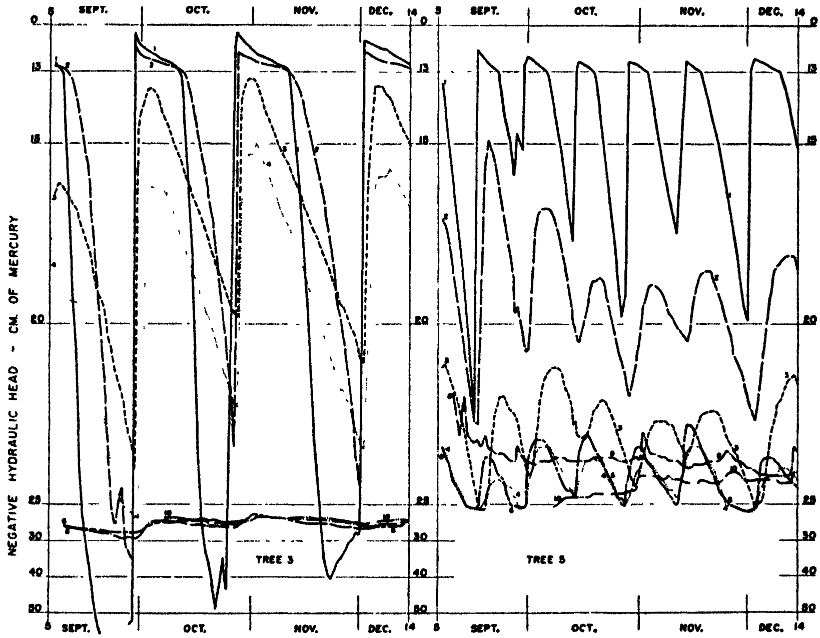

FIG. 2. Hydraulic head curves derived from the curves in Fig. 1.

in the water at the cup as in Fig. 1. Being thus measurements of hydraulic head these curves can be used for determining the direction of moisture movement in the soil (3). Flow takes place in the direction of the decrease in hydraulic head and at any given time the magnitude of the hydraulic head at the various cups is indicated by the elevation of the curves in Fig. 2.

The moisture flow pattern under tree 3 during the spring of 1940 is shown by the hydraulic head curves in Fig. 3. The soil was wetted by winter rains to the 10-foot depth and the hydraulic gradient was fairly uniform and downward in the surface 4 feet. Toward the end of February three of the curves coincided, thus indicating the hydraulic gradient was zero in the 6- to 10-foot layer and the soil moisture was at rest under gravity. The slow absorption of moisture by the roots, which is evidenced by the downward trend in the curves, then produced an upward moisture movement in the 6- to 10-foot soil layer. This

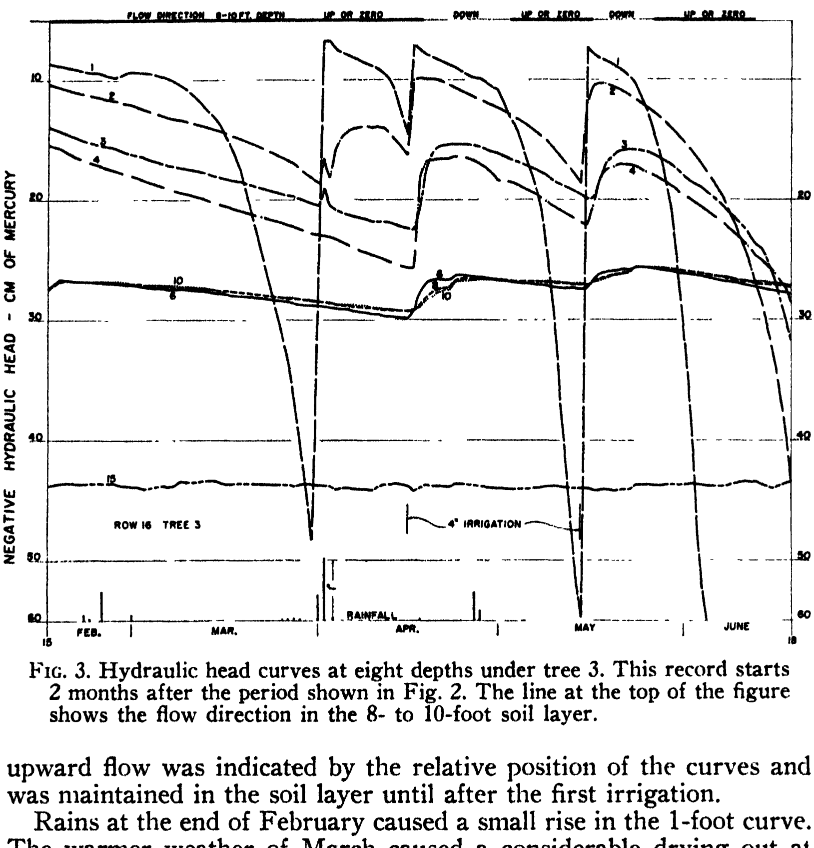

FIG. 3. Hydraulic head curves at eight depths under tree 3. This record starts 2 months after the period shown in Fig. 2. The line at the top of the figure shows the flow direction in the 8- to 10-foot soil layer.

upward flow was indicated by the relative position of the curves and was maintained in the soil layer until after the first irrigation.

Rains at the end of February caused a small rise in the 1-foot curve. The warmer weather of March caused a considerable drying out at the depth of the 1-foot cup but apparently did not appreciably affect the moisture extraction rate below the 2-foot cup. The 1½ inches of rain at the end of March affected the two surface cups only. The sharp rise in curves 2 and 3 at the time of the rain was caused by a small amount of rain water seeping down around the steel tube. The 4 inches of irrigation water applied in mid-April produced downward flow and wetting of the soil to below the 10-foot depth, but not to the 15-foot depth. The increasing downward slopes of the curves later in April was caused by the increased transpiration and it is seen that the ¾ inch rainfall of April 25 and 26 scarcely affected the 1-foot cup. Early in May the curves for the 1- and 2-foot units crossed each other, indicating the moisture flow direction in the intervening soil layer changed from down to up. At the time of the mid-May irrigation the manometer on the surface unit read nearly 60 centimeters of mercury.[3]

The mid-May irrigation produced less wetting at the 10-foot depth

[3]Centimeter of mercury is not a commonly used unit for expressing hydraulic head. Newer scales for use on mercury manometers are graduated so as to give soil moisture tension or hydraulic head directly in centimeters of water or centimeters respectively.

than the previous irrigation because the 1- and 2-foot depths were considerably drier than before. The average hydraulic gradient in the 1- to 2-, 2- to 3-, and 3- to 4-foot soil intervals reversed from down to up on May 25, June 8, and June 15 respectively.

In certain irrigated areas good irrigation practice requires at least occasionally that sufficient water be applied to the land to produce root zone leaching and thus prevent the accumulation of a harmful excess of soluble salts. The line at the top of Fig. 3 shows the flow direction in the soil layer 8 to 10 feet below the soil surface. The flow direction is down whenever the line for the 10-foot unit is above the line for the 8-foot unit. Table I summarizes flow direction data for this same layer under both trees for a 12 month period.

TABLE I—ONE-YEAR SUMMARY OF MOISTURE FLOW DIRECTION IN THE SOIL LAYER 8 TO 10 FEET BELOW TWO ORANGE TREES

Tree	Irrigation Water* (Surface Inches)	Flow Direction 8- to 10-Foot Depth					
		Days			Per Cent of Year		
		Up	Zero	Down	Up	Zero	Down
3	36	224	93	49	61.2	25.4	13.4
5	68	86	34	246	23.5	9.3	67.2

*Each tree received in addition 10.8 inches of rainfall.

Plants can grow and extract water from soils over the tension range from zero to about 15 or 16 atmospheres at the wilting point. The range for tensiometers, however, is from zero to somewhat less than one atmosphere. Under the tree with the light irrigation, all tensiometers at depths of 4 feet and below stayed on scale all year. From May to September the 1-foot unit usually went off scale before irrigation and during July and August the 2- and 3-foot units went off scale for short periods. Under the tree with heavy irrigation all tensiometers at depths of 3 feet and below stayed on scale all summer. For about a month, August 15 to September 15, the 1- and 2-foot depths were off scale preceding irrigations.

The curves in Fig. 4 show the tension variations at the cups nearest the surface that gave continuous records during the irrigation season. Again the times at which the 4-inch irrigations were applied are indicated by the tension drops in the curves. The progressive upward trend and the recession of the curves during and following the rapid transpiration part of the season is of interest. It is noted that while every irrrigation produced a certain amount of wetting, as is indicated by the tension reduction, yet the tension minima were sometimes as high as 24 centimeters of mercury. This indicates that the downward moisture movement took place at comparatively high tension and that the soil was not completely wetted to the depth of penetration of the irrigation water.

Except for minor fluctuations as indicated by the lower curve in Fig. 3 the tension at the 15-foot depth under tree 3 remained near 11 centimeters of mercury all year and was unaffected by winter rain, irri-

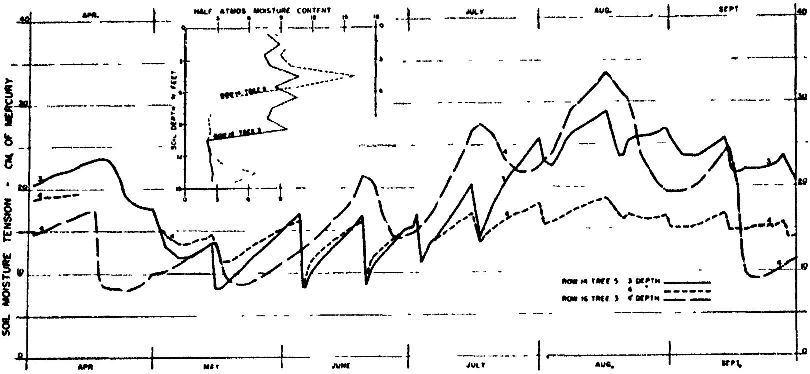

FIG. 4. Soil moisture tension curves at the 3- and 4-foot depths show that tension minima produced by summer irrigations may be as high as 24 centimeters of mercury. The inset curves indicate the variation of soil texture with depth.

gation, or the rapid summer transpiration. Under the tree with the heavy irrigation, however, the tension remained approximately constant at 12.5 centimeters of mercury during the winter but abruptly dropped to a minimum of 1.2 centimeter of mercury immediately following the first irrigation in the spring. During the next 4 months the tension slowly increased to near the former value.

Replicate installations would be required to determine how accurately one set of tensiometers indicates the moisture conditions at other locations around a tree. However, if the water input to the soil surface is relatively uniform, as is the case with level basin irrigation, field experience indicates that the moisture pattern around a tree closely follows radial symmetry for distances from the tree up to about half the tree spacing.

Tensiometers in use require refilling with water as air accumulates in the air trap. The time between refills depends on the soil moisture tension and tension fluctuations and may vary from several days to several months. The cup water comes to atmospheric pressure or higher during the refilling operation and the equilibrium manometer

TABLE II—TENSIOMETER SCALE READINGS (HYDRAULIC HEAD—CENTIMETER MERCURY) SHOWING TIME REQUIRED TO RETURN TO EQUILIBRIUM AFTER OPENING AIR-TRAPS (EQUILIBRIUM READINGS ARE SHOWN AT ZERO TIME)

Time Minutes	Steel Tube Length (Feet)			
	2	4	8	15
0	16.0	21.6	23.3	43.9
	Air-traps opened and refilled			
5	9.2	19.4	19.8	35.8
55	15.2	21.5	21.8	39.6
105	15.7	21.6	22.2	41.2
135	16.0	21.6	22.3	41.7
255	15.9	21.7	22.6	42.8

reading is again attained by the loss of water from the cup to the soil. The time required to reach equilibrium after refilling is longer when the soil moisture tension is high, especially in coarse soils, but is usually considerably less than 24 hours. The data in Table II were taken on tensiometers under tree 5 and give an indication of the rate of approach to equilibrium.

SUMMARY

A year's record has been obtained on tensiometers at eight depths down to 15 feet under two 11-year-old orange trees, one being irrigated twice as often as the other. The data provide information on the rate and depth of moisture penetration, on moisture storage and rate of root extraction at various depths, and on root zone leaching.

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Effects of Downy Spot on Photosynthesis and Transpiration of Pecan Leaves in the Fall

By A. J. Loustalot and Joseph Hamilton, *U. S. Department of Agriculture, Brownwood, Texas*

ALTHOUGH fungus diseases in general are more destructive to pecan foliage in humid regions than in dry regions, Demaree and Cole (1) have pointed out that the disease known as downy spot, *Mycosphaerella caryigena* (Ell. and Ev.) n. comb., is more injurious in the latter. These authors state that this fungus does not kill the affected leaf tissues at first but apparently destroys the chlorophyll and subsequent reduction in photosynthesis may be expected. While the disease has never been known to cause defoliation during the summer, badly infected leaves ordinarily drop off in the early fall.

It has been shown by Heinicke (4) and others that the amount of carbohydrates a tree synthesizes during a season is one of the important factors in fruit production. Smith and Waugh (7) found that starch decreased rapidly in the roots of pecan trees during early spring growth, and starch and hemicellulose decreased during the period of kernel development in the nuts. They also showed that the starch concentration in the roots in the fall apparently influenced fruiting the next spring. Thus it appears that the filling of pecan nuts and the storage of material required for early growth and fruiting in the spring are largely dependent on the amount and character of the foliage and the length of time it functions on the tree. Therefore, it seemed worthwhile to determine to what extent downy spot affects the photosynthetic activity of pecan leaves.

The data presented in this paper show the comparative rates of CO_2 assimilation and transpiration of healthy and diseased pecan leaves late in the season of 1940.

Materials and Methods

The apparatus and procedure for measuring photosynthesis were similar to those used by Heinicke and Hoffman (3). The experimental set-up consisted of six carbon dioxide absorption towers, two of which were attached to healthy leaves, two to diseased leaves, and two served as air checks. The assimilation chambers, or leaf-cups, were made from half-pint whisky bottles cut in half (with hydrofluoric acid) and were similar in design to the leaf-cups described by Heinicke (2). These chambers are particularly suitable for use with pinnate type leaves such as those of the pecan because of their oval shape. The leaf-cups were supported on tall ring stands with adjustable side arms which permitted full exposure of the experimental leaf area to light. Preliminary determinations with cellophane bags as assimilation chambers proved unsatisfactory because the leaf tissues were injured by high temperatures inside the bags on prolonged exposure to sunlight. It has been pointed out (3) that more nearly natural conditions of light, temperature, and relative humidity are provided with the cup-chambers than with the cellophane bags. The cup-chamber has the added advantage that it encloses a definite leaf area which in this experiment was 30 cm^2.

A continuous stream of air at the rate of 2 to 2½ liters per hour per square centimeter of leaf area (3) was drawn through the chamber. The water transpired by the leaf was determined by weighing, after passing the air through a dehydrating agent (pumice stone impregnated with sulfuric acid) before it reached the CO_2 absorption tower (5). The volume of air passing through each absorption tower was accurately measured by a wet test flow meter.

The experiments were conducted with the leaves of a 9-year-old pecan tree of the Western variety growing near the laboratory of the United States Pecan Field Station at Brownwood, Texas. The tree was in good vigor and bore a fair crop of nuts which was not harvested until the experiment was terminated, although the nuts were ripe at the beginning of the experiment. The tree was sprayed in early summer with zinc sulphate (1½ to 50) to control rosette.

The experiments extended from October 21 through November 14, 1940. Mature leaves on the east side of the tree, which were exposed to full sunlight from 9:30 a.m. to 1:00 p.m. and which were in full shade for the remainder of the day, were selected for the determinations. These leaflets were mildly infected with downy spot, about 5 per cent of the ventral surface being affected at the outset. At the end of the experiment approximately 20 per cent of the area showed lesions. The normal tissue consisted of two lateral leaflets located on the same branch about 1 foot from those that were diseased. At the time the determinations were started the normal leaflets appeared dark green and healthy. However, by November 2, both types of leaflets, and particularly the diseased ones, showed symptoms of senescence which became more apparent as time went on. Records on the carbon dioxide assimilation and transpiration rates for the daily periods from 9:30 a.m. to 1:15 p.m. were obtained from October 21 through November 14 when a heavy frost caused abscission of the leaflets. Data for the intervals from 1:30 p.m. to 4:30 p.m. were obtained daily from October 22 through October 31. Weather observations, including temperature and relative humidity, were made at the beginning, the middle, and the end of each determination. The data are presented in Fig. 1.

Results and Discussion

In most instances the photosynthetic activity of the diseased leaflets was considerably lower than that of the normal leaflets (Fig. 1). However the differences were less apparent during the afternoons than in the mornings. The average daily assimilation rate of the normal leaflets for the morning periods (23 determinations) was 4.59 milligrams CO_2 per 100 cm^2 per hour, while that of the diseased leaflets was 3.13 milligrams or 1.46 milligrams less than that of the normal leaflets. Expressing this difference on a percentage basis, the diseased leaflets were 31.8 per cent less efficient in assimilation of carbon dioxide. In the afternoon periods which included nine determinations, the average rate for the normal leaflets was 3.38 milligrams per 100 cm^2 per hour as compared with 2.63 milligrams for the leaflets infected with the fungus; a reduction of 22.2 per cent in efficiency. On the whole the relative assimilation rates of the normal and diseased leaflets were

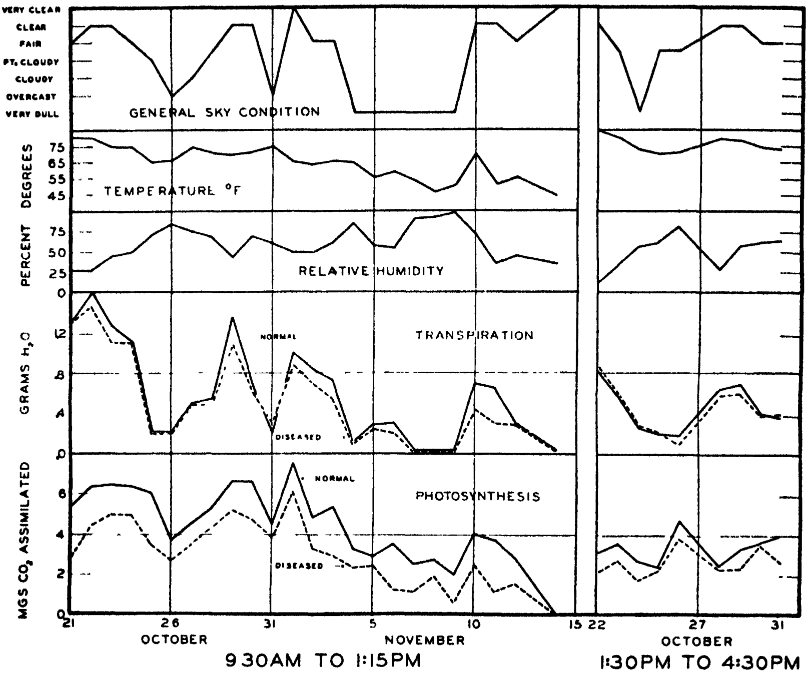

FIG. 1. Carbon dioxide assimilated and water transpired by normal and diseased pecan leaves under varying weather conditions.

closely maintained throughout the experiment, the fluctuations in activity of both kinds of leaflets being affected in a similar manner by changes in weather conditions.

The average daily transpiration rate of normal leaflets for the morning periods was 0.55 grams of water per 100 cm^2 per hour as compared with 0.47 milligram for the diseased leaflets. For the afternoon periods the average daily rates were 0.48 milligram and 0.46 milligram respectively for normal and diseased leaflets. Thus the average daily rate of transpiration of normal leaflets for both the morning and the afternoon periods was higher than that of diseased leaflets but for the latter periods it was only slightly higher.

Although the average daily rate of transpiration was higher in normal leaflets than in diseased leaflets, this was not true for all the individual daily rates. On clear, warm mornings when the relative humidity was low, comparatively high transpiration rates were recorded for both types of leaflets and the rates for normal leaflets were considerably higher than those for diseased leaflets. On cool, moist, cloudy mornings the differences were less apparent or lacking, and in one instance, October 31, the diseased leaflets transpired at a slightly higher rate than the normal leaflets. The diseased leaflets also showed a slightly higher rate during several of the afternoon periods regardless of weather conditions.

The first severe frost of the season occurred during the night of

November 11–12, and although weather conditions the following morning were favorable and there was no apparent injury to the leaves, the values obtained for the photosynthesis and transpiration rates were relatively low. Little or no activity was observed for the last determination, two days later, when the tree was nearly defoliated.

While the daily fluctuations in transpiration and apparent photosynthesis were evidently related to corresponding fluctuations in light and other meteorological factors, the general trend was toward a slowing down of these processes as the season advanced.

The correlation between photosynthesis and transpiration during the morning intervals was very striking. As a rule, on days when assimilation rates were high transpiration rates were high, and vice versa. In general, the transpiration and assimilation rates in the afternoon were much lower than those of the forenoon. This is to be expected for several reasons. First, and perhaps most important, the leaves were in full shade during the afternoon periods; secondly, it has been shown (6) that stomates normally tend to close in the afternoon, thereby slowing up exchange of gases. The accumulation of products elaborated in the morning might be expected to have a retarding effect on subsequent assimilation. It is noted in this connection that both the photosynthesis and transpiration rates were low for the morning of October 26, while for the afternoon of the same day the photosynthesis rate was high and the transpiration rate was low. Obviously there is a combination of external and internal factors in operation which influence these physiological processes from day to day and during the same day.

In general, the relationship between photosynthesis and transpiration in the afternoon was the reverse of that in the morning, that is relatively high rates of water loss corresponded to low carbon dioxide absorption, and vice versa.

TABLE I—CARBON DIOXIDE ASSIMILATION AND TRANSPIRATION RATES OF EIGHT PAIRS OF NORMAL AND OF DISEASED LEAFLETS[*] NOVEMBER 1–6, 1940

Sky Condition	Average Temperature (Degrees F)	Average Relative Humidity (Per Cent)	Estimated Degree of Fungus Infection of Diseased Leaflets	CO_2 Assimilated Per 100 Cm^2 Per Hour		Water Transpired Per 100 Cm^2 Per Hour	
				Normal (Mgs)	Diseased (Mgs)	Normal (Gms)	Diseased (Gms)
Very clear.....	66	50	Mild	7.53	6.13	1.04	0.94
Very clear. ..	72	33	Considerable	9.40	4.23	1.32	0.79
Very clear .	75	33	Considerable	5.45	2.89	0.40	0.41
Intermittent sunshine ...	71	31	Moderate	6.59	4.54	0.87	0.85
Intermittent sunshine ...	66	61	Considerable	5.38	2.88	0.75	0.55
Overcast, hazy, light shower	66	91	Considerable	1.73	0.46	0.04	0.03
Overcast part time	57	50	Moderate	4.04	2.49	0.27	0.20
Part cloudy...	62	60	Moderate	5.56	3.61	0.34	0.35
Average ..				5.71	3.40	0.63	0.52

Difference milligrams CO_2 assimilated, 2.31; standard deviation, 1.25**
Difference grams H_2O lost, 0.11; standard deviation, 0.19.
*Each determination represents the average of two normal and two diseased leaflets. Each series consisted of one pair each of normal and diseased leaflets.
**Highly significant.

Since only one pair each of normal and diseased leaflets was used in the main experiment, it was deemed advisable to make tests of other leaflets so as to determine whether the differences obtained might be due to variation in the material.

Eight series consisting of one pair each of normal and diseased leaflets, comparable in position and exposure to light, were selected for these tests. Photosynthesis and transpiration determinations during 3-hour periods[1] were made in the afternoons using different pairs of leaflets for each period. The data which are presented in Table I are in accord with those obtained with corresponding pairs of leaflets in the main experiment. The average photosynthetic activity of diseased leaves was 40.45 per cent lower than that of normal leaves, and the transpiration was less by 17.46 per cent. Thus, the data show definitely that downy spot decreases the two processes in pecan leaves.

Summary

The data obtained in this study clearly show that photosynthesis was markedly reduced in pecan leaves as a result of downy spot infection. The reduction was somewhat greater than would be expected from the extent of leaf surface apparently invaded by the fungus. Both healthy and diseased leaves continued to function late in the season but with a gradual decline in rate, until abscission occurred as the result of a severe frost.

On the average, the infected leaves also transpired less than normal leaves but there were some exceptions, particularly when the leaves were in the shade and when conditions for evaporation were unfavorable. For the morning periods high rates of carbon dioxide absorption generally corresponded with high transpiration rates and vice versa, whereas for the afternoon periods the relationship of the two processes was usually reversed. There was a close parallel in daily fluctuations of photosynthesis and transpiration of healthy and diseased leaves due to differences in weather conditions.

The authors are indebted to Dr. C. L. Smith for helpful suggestions and assistance in the preparation of the manuscript.

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[1]The determinations on November 1 lasted 1½ hours.

A Rapid Method of Determining When A Plant is Killed by Extremes of Temperatures[1]

By G. A. Filinger and A. B. Cardwell, *Kansas Agricultural Experiment Station, Manhattan, Kans.*

ONE of the problems in studying hardiness of plants is to determine just when a plant was killed. The procedure has been to place plants or plant parts under favorable growing conditions following exposure to temperature extremes. If they grew, the treatment had not killed them. If they failed to grow, the worker never was sure whether the exposure killed the plant, and if so, what was the lethal point, or whether the plant died subsequent to the treatment.

A method devised at the Kansas Agricultural Experiment Station seems to indicate when a plant has been killed by temperature extremes. The equipment used in this method was set up in connection with a study of hardiness of bramble canes. It was found that when canes were killed by freezing or by boiling, they offer less resistance to electric current than when alive. Resistance measurements were made with a standard bridge for electrolytic resistance. The bridge was energized by a 1,000 cycle source. A vacuum tube voltmeter, using a 6E5 (electric eye) vacuum tube, served as a detector. Contact with the cane under test was made by inserting steel needles 10 inches apart through the cane. Fig. 1 illustrates the equipment used.

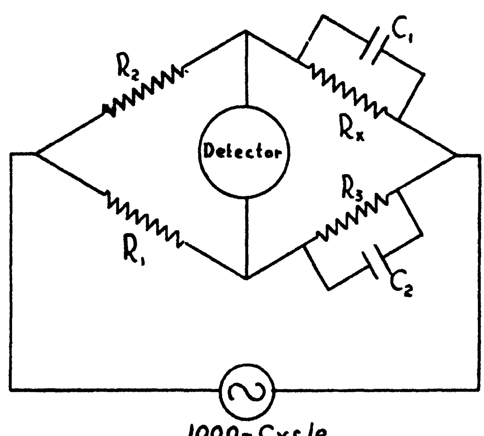

Fig. 1. Diagram showing equipment used in determining electrolytic resistance of raspberry canes. R_1 R_2 + R_3 are L + N No. 4748 resistance boxes, Rx—Resistance of the raspberry cane, C_1—Capacitance of the raspberry cane, C_2—Variable capacitance.

Red raspberry canes which had been collected in October 1940 before any freezing weather and stored at about 36 degrees F were used in the first studies. The canes were cut into 12-inch lengths and the needles inserted 1 inch from each end of a cane. Thus the resistance of a 10-inch piece was recorded in each case. The results of preliminary work are presented in Table I.

It will be noted that resistance was reduced 72 to 82 per cent by killing the canes by freezing or boiling.

In order to check the consistency of subsequent readings on the

[1]Contribution No. 177, Department ot Horticulture.

TABLE I—ELECTROLYTIC RESISTANCE OF RED RASPBERRY CANES (AVERAGE RESISTANCE OF 10 READINGS)

Variety	Before Treatment (Ohms)	After Freezing* (Ohms)	After Boiling† (Ohms)	Reduction (Per Cent)
Chief	235,200	65,880	—	72.0
Chief	276,800	—	65,160	76.5
Latham	307,640	81,520	—	72.7
Latham	456,000	—	78,920	82.7

*Placed in liquid air.
†Placed in water at 95 degrees C for 3 minutes.

same canes, the resistance of 10 untreated live canes was determined and rechecked in 4 days. The canes were then placed in a warm room, with the lower end of each cane in water and rechecked when growth started. These data are presented in Table II.

TABLE II—ELECTROLYTIC RESISTANCE OF RED RASPBERRY CANES

Variety	Average First Reading (Ohms)	Four Days Later (Ohms)	When Growth Started (Ohms)
Chief	230,080	217,200	214,480
Latham	322,000	322,800	220,120

The resistance was consistent, being reduced somewhat when growth started.

Some growing canes of Chief and Latham raspberries were cut into 12-inch lengths on June 21, 1941, and their resistance determined as before. Ten were then frozen with liquid air and 10 frozen at 0 degrees F. The resistance was determined following the freezing and the results are presented in Table III.

TABLE III—ELECTROLYTIC RESISTANCE OF CURRENT SEASON CANES (AVERAGE RESISTANCE)

Variety	Before Freezing (Ohms)	After Freezing (Ohms)	Reduction (Per Cent)
Chief	162,800	22,360*	86.26
Latham	138,800	14,240*	89.74
Chief	159,600	14,880†	90.68
Latham	128,000	16,480†	87.13

*Frozen in liquid air.
†Frozen at 0 degrees F.

The same marked reduction in electrolytic resistance will be noted.

This method of determining when a plant is dead by reading the electrolytic resistance of the plant or plant part has the following advantages:

1. It is a rapid method.
2. A portable apparatus could be taken to the field and plants studied after each adverse weather period.
3. The plant need not be destroyed to make a determination.

Delayed Foliation of Pecan Trees in Arizona[1]

By CLIFTON W. VAN HORN, *U. S. Department of Agriculture, University of Arizona, Tucson, Ariz.*

IT HAS been suggested (2) that the cause of unsatisfactory production of some pecan varieties in the arid Southwest is possibly associated with incomplete dormancy as induced by the characteristic warm sunny winters having relatively few hours of chilling. Chandler *et al* (1) have pointed out that many plants have definite chilling requirements for proper opening of the buds, and that reduced light intensity reduces the absorption of heat and thereby increases the actual chilling which the buds receive. They state that "...areas which have regular fogs have greater chilling of buds by a reduction in absorption of heat."

Low yields of pecans follow either a light blossom or an excessive drop of blossoms or young nuts. Insufficient chilling is possibly a contributing factor causing either or both of these. Waite (4) in discussing factors influencing the setting of nuts and fruits in 1925 pointed out that, "The pecan undoubtedly requires for best results a well-defined resting period and probably the feeble growth and lack of vigor of some of the southernmost plantings...are attributable to this factor more than anything else."

With some varieties of pecan trees in the arid Southwest, the northeast side of the tree grows and fruits quite differently from the southwest side. On it, buds break first in the spring, longer current season's growths are produced, larger leaves are developed, more pistillate blooms are formed, and more nuts are produced as compared to the southwest side of the same tree. To consider some of the factors associated with these conditions and their possible relation to insufficient winter chilling is the purpose of this report.

Data presented are from three separate regions within the State of Arizona: (a) The Yuma Valley which lies on the eastern bank of the Colorado River close to the Mexican boundary and has an elevation of about 140 feet above sea level; (b) The Salt River Valley located in the south central part of the state at an elevation of about 1100 feet; and (c) The Safford Valley located in the central eastern part of the state and having an elevation of approximately 2900 feet and lying on the northerly slope of the Graham Mountains which rise to an elevation of 10,500 feet. Because of differences in elevation these districts differ in number of hours of chilling experienced during the winter months.

This report deals primarily with the Burkett and Humble varieties. The Burkett has been the most widely planted in Arizona; it apparently is a variety seriously affected by delayed foliation. There are only a few trees of the Humble planted within the state; it seems to tolerate warmer winter temperatures than many varieties since it shows fewer symptoms of delayed foliation.

Because of differences in soil, type of culture, and age of trees exact comparisons between varieties and locations of course, cannot be made.

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[1]This paper is a joint contribution of the Arizona Agricultural Experiment Station and the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

Methods and Presentation of Data

Forty-five degrees F has been used as a base from which the number of hours of chilling has been calculated from thermograph records for the three Arizona valleys. Table I presents these data.

TABLE I—Hours of Chilling (45 Degrees F or Below) Recorded for Yuma Valley, Salt River Valley (Tempe, Arizona) and Safford Valley for Indicated Periods

Location	Elevation Above Sea-Level (Feet)	Hours of Chilling		
		Average 1930–31 to 1938–39	1939–40	1940–41
Yuma	140	879	693	548
Tempe	1100	1174	841	685
Safford	2900	——	1382	1476

An available record for another locality in which pecans are grown is that reported by Weinberger (5) for Fort Valley, Georgia. For the 1938–39 season he reported 1,127 hours of 45 degrees F or below.

The 1940–41 season in Arizona had more cloudy days than normal. Delayed foliation symptoms were reduced. This called attention to the sunshine factor as affecting chilling conditions on pecans. Gordon (3), weather observer at Yuma, says that in Yuma, "The sun does not shine all of every day but it comes nearer doing that than in any other part of the United States for which we have record." Table II shows the percentage of possible sunshine at Yuma as contrasted with other points in or near pecan growing regions.

TABLE II—Sunshine During the Winter Months at Various Points Near Where Pecans Are Grown*

Location	Percentage of Possible Sunshine						Variation From Yuma Average					
	Oct	Nov	Dec	Jan	Feb	Mar	Oct	Nov	Dec	Jan	Feb	Mar
Yuma, Arizona												
32-year average	93	89	82	81	84	89	—	—	—	—	—	—
1938–39	96	94	83	84	75	85	+3	+5	+1	+3	−9	−4
1939–40	98	85	96	80	83	90	+5	−4	+14	−1	−1	+1
1940–41	92	87	72	69	77	86	−1	−2	−10	−12	−7	−3
San Antonio, Texas (Average)	66	53	50	52	53	56	−27	−36	−32	−29	−31	−33
Meridian, Mississippi (Average)	66	61	43	46	49	58	−27	−28	−39	−35	−35	−31
Atlanta, Georgia (Average)	66	61	60	47	54	57	−27	−28	−22	−34	−30	−32
Thomasville, Georgia (Average)	63	65	51	53	53	63	−30	−24	−31	−28	−31	−26

*Data furnished by the United States Weather Bureau, Yuma, Arizona.

The 1938–39 and 1939–40 dormant seasons were followed by delayed foliation symptoms of the Burkėtt pecans at Yuma. It is apparent that from October through March, Yuma has about 30 per cent more of the possible hours of sunshine than any of the other regions indicated in Table II.

In 1937, preliminary work was done on the use of certain chemicals to overcome delayed foliation of the pecan at Yuma. During the 1937, 1938, and 1939 seasons results were obtained from the use of ethylene gas, ethylene chlorohydrin, chilling of individual twigs, and a dormant spray of 2–4–dinitro–6–cyclohexylphenol in oil (DNO). The latter material only was used in 1940 because a spraying method was considered to offer the most practical solution to the problem. In 1940 four applications of the dormant spray were applied to 9-year-old Burkett trees. Dates of application were February 1, 13, 24 and March 7. The material, consisting of a 3 per cent DNO (4 per cent of the 2–4–dinitro–6–cyclohexylphenol and 96 per cent oil), was applied at the rate of 50 gallons for six trees. The following definite responses were noted: An advance in date of foliation, a more uniform breaking of buds, an increase in rate and amount of shoot growth, and an increase in leaf size. However, no marked increase in yield of nuts occurred—probably because these trees blossomed too early to have sufficient pollen available for proper pollination.

In 1941, applications of DNO were made on the same dates as in 1940, both at Yuma and at Safford. Another series of trees were given a single application of a 2 per cent solution of DNO on February 20, which was selected as being about 30 days in advance of the normal time of bud breaking for the Burkett variety. Other trials were made with this DNO material as a liquid miscible in water (Dowspray Dormant No. 2), and as a powder form soluble in water (DN Dry Mix). Two dinitro-cresol compounds (Elgetol and Vapo Elgetol) were also tried as well as an emulsion of a light petroleum oil. The most pronounced response at Yuma in these 1941 trials was from the repeated application of the DNO in oil on the Burkett variety.

In 1940, dates were recorded when the first buds were breaking on DNO-treated and check Burkett trees at Yuma. In 1941, similar records for the Burkett were obtained at Yuma and Safford and for the Humble variety at Yuma. Table III presents these data.

TABLE III—Comparison of Dates When Pecan Buds Break in the Spring

Location	Season	DNO		Check	
		Burkett	Humble	Burkett	Humble
Yuma................	1940	March 7	———	March 20	March 27
	1941	March 6	March 4	March 18	March 21
Safford................	1941	April 1	———	April 1	———

Trees treated with DNO broke into leaf about 2 weeks in advance of checks at Yuma whereas at Safford DNO-treated trees and checks foliated at the same time. At Yuma buds opened from 1 to 6 days earlier in 1941 than in 1940. At Safford the temperatures were so much cooler than at Yuma that buds did not open until the first of April.

On April 3, 1940, DNO-treated Burkett trees at Yuma were considerably advanced as compared with the checks in the amount of growth and foliage. Fig. 1, A and B illustrate these differences.

FIG. 1. Character of foliation of Burkett trees at Yuma in 1940. A, Four dormant applications of DNO resulted in buds breaking March 7, 1940. B, Check tree had buds breaking March 20, 1940. Southwest side of each tree is on the left. Photo April 3, 1940.

In Fig. 1, B the southwest side (left side of this photograph) was not as far advanced as the northeast side of the tree.

On April 3, 1941, the DNO-treated Burkett trees at Yuma were again considerably advanced as compared with the checks. However, delayed foliation was less apparent on Burkett checks at Yuma in 1941 as revealed by the fact that opening of buds on the southwest side of tree occurred at nearly the same time as those on the northeast side.

Opening of buds was considerably delayed on the Burkett variety at Safford in comparison with Yuma. The first buds opened at Safford on April 1, 1941 on both DNO-treated limbs and checks. On check trees practically no differences in time of bud opening could be noted between southwest and northeast sides of trees. Under the Safford conditions no definite response was obtained from the four dormant sprays of DNO.

Trees of the Humble variety at Yuma treated in 1941 with DNO were opening buds 2 days earlier than Burketts similarly treated, while Humble checks were 3 days later than untreated Burkett. Foliation of DNO-treated Humble trees was advanced 17 days in comparison with check trees.

The observation was made in both 1939 and 1940 that those trees which because of reduced vegetativeness in the late summer matured and dropped their leaves first, were the first to break dormancy the following spring.

At Yuma in 1941 other pecan varieties, which responded to the DNO treatment by a definite advance in the date of breaking of buds as compared to checks were Halbert, Desirable, and Schley. The Success variety alone did not respond.

Observations made in the Salt River Valley on April 12, 1941 indicated that untreated Burkett trees were only a few days later than

those at Yuma. Their stage of development was more nearly like those at Yuma than those at Safford.

In 1940 and 1941 shoots which had fruited the previous season were selected before growth started. The shoots which developed from these selected twigs were measured at 2-day intervals and their growth rate plotted. Only those shoots which produced blossom clusters have been included in the data. Twenty-one such shoots was the greatest number obtained so these growth rate curves cannot be considered particularly accurate but they show the situation commonly observed in the orchard. The data for the Burkett variety are shown in Fig. 2.

Trees treated with DNO started growth earlier and made greater total growth than check trees. The southwest sides of these treated trees made more growth than the northeast. In 1940 the northeast side of the check tree made considerably more growth than the southwest side while in 1941 following a relatively cloudy winter this difference was very slight. A more uniform absorption of heat is believed to account for this.

One Burkett treated tree which responded to DNO in 1940 failed to foliate earlier when treated in 1941.

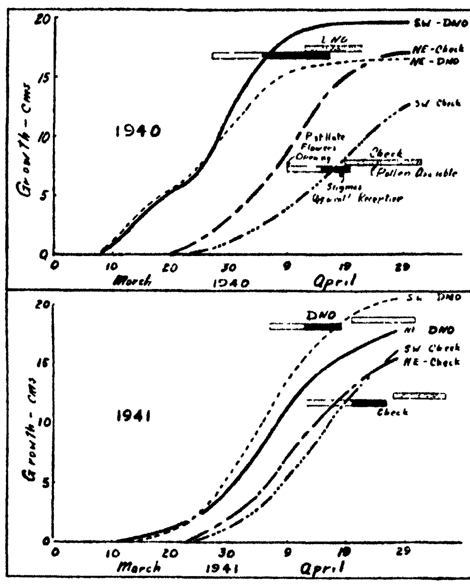

FIG. 2. Graph showing linear shoot growth and blossoming periods for DNO treated and check Burkett trees (Yuma, 1940 and 1941).

Measurements made on the Humble variety in 1941 indicate that it makes slightly less than half the total growth of the Burkett. The DNO treatment increased this only slightly.

In 1940 leaves from the northeast side of untreated Burkett trees were definitely larger than those from the southwest side while in 1941 this difference was greatly reduced. The DNO treatment tended to obscure this difference but did not overcome it entirely. A similar though smaller difference in leaf size is to be found in the Humble.

In Fig. 2 the periods of pistillate and staminate flowering are shown. Pistillate flowers were considered open when each could be distinguished as an individual in the cluster. The date when the majority of the stigmas were apparently receptive is indicated. When stigmas began to dry they were considered to be definitely past receptivity. The period between the first and last available pollen is

TABLE IV—BLOSSOMING PERCENTAGES FOR THE NORTHEAST AND SOUTHWEST SIDES OF UNTREATED BURKETT AND HUMBLE TREES AT YUMA, SALT RIVER VALLEY, AND SAFFORD

Location	Variety	Number Trees Averaged	Northeast (Per Cent)	Southwest (Per Cent)
		1940 Season		
Yuma	Burkett	18	46.9	37.5
Salt River Valley	Burkett	3	42.6	39.5
Safford	Burkett	6	47.5	48.1
Yuma	Humble	7	48.4	49.3
		1941 Season		
Yuma	Burkett	10	54.3	55.3
Salt River Valley	Burkett	3	60.4	51.1
Safford	Burkett	5	58.3	56.7
Yuma	Humble	13	49.1	55.0
Salt River Valley	Humble	3	64.3	59.7

indicated for each tree.

It is evident that the flowering period is advanced by the DNO treatment but that the relationship between pistillate receptivity and pollen shedding is unchanged.

Blossoming percentages were obtained for both the northeast and southwest sides of untreated trees by determining the number of blossom clusters produced on approximately two hundred growing points. These data were taken in the three Arizona valleys and are given in Table IV.

In 1940 Burkett trees at Yuma had a greater blossoming percentage on the northeast side of the trees. This difference also showed up in the Salt River Valley but to a lesser extent, while at Safford there was but little difference between the two sides of the trees. The 1940 Humbles at Yuma blossomed like the Burketts at Safford. In 1941 Burketts at Yuma had approximately the same blossoming percentage on both sides. In the Salt River Valley and at Safford the southwest side was reduced in comparison with the northeast. In all three valleys the 1941 blossoming percentages tended to be greater than those of 1940. The southwest side of the Humbles at Yuma in 1941 again had a greater blossoming percentage while in the Salt River Valley the northeast side produced more than the southwest.

Treatments with DNO at Yuma on Burketts tended to increase the blossoming percentage while there was practically no effect on Humbles.

In 1940 the number of nuts which dropped from the tree was obtained by attaching from 100 to 250 tags on individual clusters of pistillate blossoms on both the northeast and southwest sides of the trees. The nuts in individual clusters were counted at weekly intervals from April 2, 1940 to early in June. The percentage of nuts set was calculated for each date by using the original number of nuts as 100 per cent.

Graphs of these data are not presented here, but they indicate for the Humble that the greatest loss of nuts occurred before the first of May. For the Burkett this loss of nuts seems to occur over a longer period. Typical examples for the two varieties show the trend in the

percentage of nuts set from the original number of flowers. These are: on June 4, 1940 the Humble had set 73.1 per cent on the northeast and 68.1 per cent on the southwest, while the Burkett had set only 44.8 per cent on the northeast and 25.5 per cent on the southwest. Nineteen, 9-year-old Burkett trees which had been grown under a low nitrogen type of culture averaged 613 nuts from the northeast side and 415 nuts from the southwest side. Fourteen 6-year-old Humble trees averaged 602 nuts from the northeast side and 532 nuts from the southwest side.

Discussion

The number of hours of chilling offers one measurement of a factor apparently affecting performance of pecans in Arizona. The most obvious symptom of delayed foliation is the opening of buds on one part of a tree when other buds are still dormant. The most uneven breaking of buds or delayed foliation is found in the lower valleys where there are the fewest hours of chilling. Delayed foliation is practically always evidenced by the opening of buds on the northeast side of the trees several days before those on the southwest side.

"Hours of chilling" represents a measurement of air temperatures. While all portions of a tree would be surrounded by approximately the same temperature dormant buds have different exposures to sunshine. Greater absorption of heat by the buds on the southwest side of the trees seems to be a reasonable expectation and may account in part for the greater delayed foliation. The possibility suggests the need of measuring internal temperatures of buds especially as affected by solar radiation or exposure to sunshine. The percentage of possible sunshine at Yuma in 1940–41 was somewhat below the average, and symptoms of delayed foliation were much less noticeable than in most former years. From weather bureau records it appears that at Yuma, dormant pecan buds are exposed to approximately 30 per cent more of the possible hours of sunshine, as compared to other pecan regions. This difference may cause sufficient difference in heat absorption to account for the greater delayed foliation in the lower Arizona valleys in comparison with other pecan growing regions even though the total hours of air chilling may not be very different.

DNO has been found to be quite effective in stimulating initiation of growth within certain pecan varieties at Yuma. This stimulation apparently compensates for some lack of chilling. When this material was applied to Burkett trees in 1941 at Safford, where there was apparently ample chilling, no stimulating effect was noted. The Humble variety seems to require fewer hours of chilling for normal foliation than the Burkett, so that the DNO treatment stimulates it into growth more rapidly.

Shoot growth, size of leaves, percentage of shoots forming pistillate blossom, percentage of blossoms to set nuts, and yield of nuts are other measures of response to the different conditions. They may be used as additional symptoms of delayed foliation.

Treatment with DNO apparently increased the total growth of Burkett shoots more in 1940 than in 1941. Check trees in 1940 made more growth on the northeast side than the southwest side. In 1941

this difference was greatly reduced adding more evidence that there was considerably less delayed foliation in 1941 than 1940. Leaves were also more nearly the same size on both sides of the tree in 1941.

Blossoming percentages were also more nearly alike on both sides of the tree in 1941 for untreated Burkett trees especially at Yuma. The DNO treatments increased the blossoming percentages so that the southwest side was nearly comparable to the northeast. At Safford, Burketts normally blossom about equally on both sides of the tree. Apparently extreme delayed foliation is one cause for low blossoming percentages. There is also evidence that it decreases the percentage of nuts set. This effect is easily obscured, however, by differences in nutrition. It appears that blossoming in the Humble at Yuma is influenced more by nutrition than by delayed foliation.

Both the percentage of nuts set and production in 1940 show the Burkett to have been considerably more affected by delayed foliation than the Humble. The northeast side of Burketts not only had a greater blossoming percentage but also matured more nuts. Humbles do not show these extreme differences between the two sides of the tree indicating that they are much less affected by delayed foliation than Burketts.

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Root Distribution of Young Avocado Trees on Bench Terraces

By MAURICE DONNELLY, *University of California and U. S. Soil Conservation Service, Riverside, Calif.*

BENCH terraces have been widely used in both the Old and the New World. As an indication of their importance in permanent land use, Lowdermilk[1] found from a study of land use in Europe that only two classes of land had withstood continuous cultivation for a thousand years or more; level or gently sloping land not subject to the soil erosion processes, and land artificially leveled, in part, by bench terracing.

In the semiarid Southwest, Stewart and Donnelly (11) found evidence of numerous bench terraces that had been used by the primitive pueblo farmers of that region. At the present time, the Dutch and English in the East Indies employ bench terracing on an extensive scale in tree cropping. In California, bench terraces are used currently to a limited extent in citrus culture and to a considerable extent in avocado culture.

Little has been reported on the effect of bench terracing on root systems of tree crops. In fact, insofar as the avocado is concerned, there seem to be almost no published accounts of systematic root studies. Of 3,650 references to the avocado compiled by Condit (4) in 1939, none, if one may judge by the titles, are concerned primarily with the root system. Coit (3), in 1940, published a short but illuminating paper, illustrated with diagrams, on the general effects of soil and culture on the root system of the avocado.

Only a small body of literature on the root systems of some of the other fruit trees has accumulated, much of it appearing within the last 10 years. While no attempt will be made here to review this literature, several of the more recent references may be cited. In reporting a comprehensive study of the root systems of young apple trees, Yocum (19) gave a critical review of the pertinent literature, citing 56 titles. Rogers (9) contributed a historical survey of 118 papers bearing on root growth, with special reference to hardy fruit plants. These 118 papers were selected from more than 1,100 works dealing with or mentioning root growth. Among recent papers that have appeared since the time of the foregoing reviews, or that were not included in them, are those by Batjer and Sudds (1), Boynton and Savage (2), Haut and Schrader (6), Lincoln (8), Rogers (10), Susa (12), and Tydeman (13, 14) on apple tree roots; by Cowart (5) and Havis (7) on peach tree roots; and by Veihmeyer and Hendrickson (15) on soil moisture as an indication of root distribution in deciduous orchards.

The principal object of the present study was to gain information on the effect of bench terracing on the root distribution, particularly the horizontal root distribution, of the avocado. Field work was carried on at the hillculture research station operated jointly by the University of California and the United States Soil Conservation Service, near

[1]Lowdermilk, W. C., in oral communication to the writer.

San Juan Capistrano, California. This station is in the coastal section of the subtropical belt.

The Four Types of Bench Terraces

Four types of bench terraces were included in the study: the preformed or preconstructed bench terrace, the level-basin bench terrace, the Reddick bench terrace, and the Javanese bench terrace.

In the construction of the preformed terrace, a line is laid out on grade along the hillside. By repeated slices soil is moved downhill along this line by a tractor-drawn scraper until a platform nearly level in cross section is formed, which constitutes the bench proper. The steep section just below the platform or bench is called the riser. The width of the bench in the preformed terraces at Capistrano ranges between 7 and 12 feet. Avocados were planted on these preformed terraces 2 feet from the outer edge of the bench.

Level-basin terraces are constructed by manually excavating, with shovels, a circular basin, the central portion of which is level. The level-basin terraces involved in this study measure 8 feet in diameter. Avocados were planted in the center of these basins.

The Reddick bench terrace is a California adaptation of the accretionary type. In constructing this terrace, a furrow ridge is thrown up by plowing along a predetermined grade. Trees are planted on this ridge. The soil immediately adjacent to the upper side of the tree row is cultivated; the soil immediately below is maintained in ground cover. This results in a gradual movement of soil downhill on the cultivated strip and its entrapment on the uncultivated strip, a process which results in time, generally in from 2 to 10 years, in the development of a bench on the upper side of the tree. In this experiment, the horizontal distance between two adjacent ridge lines is 16½ feet at a position on the hillside where the slope is average for the area so terraced.

The Javanese bench terrace, developed in the East Indies, differs from most bench terraces built in the New World in that part of the earth is moved uphill. As in the construction of a preformed terrace, a line is laid out along the hillside to a predetermined grade. Some soil is moved downhill along this line by manual or mechanical cut-and-fill methods. Part of the bench is formed by this downhill earth displacement. The remainder of the bench is formed by moving earth uphill from a strip just below the grade line. This method of bench-terrace formation lessens the extent to which subsoil is exposed at the surface by the terracing operation. As in the preformed terrace, trees are planted near the outer edge (in the present study, 2 feet from the edge) of the bench.

In this experiment, Reddick bench terraces were built on a southerly exposure, the slope ranging from 20 to 35 per cent; level basin terraces were constructed on a southerly and a northerly exposure on slopes ranging from 15 to 25 per cent; preformed terraces were constructed on both northerly and southerly exposures, with slopes ranging from 18 to 35 per cent; and the Javanese terrace was formed on a northerly exposure having a 30 per cent slope.

THE SOILS

The subjoined profiles are representative of the soils assemblage on which plantings were made. Profiles A to E, listed below, are of soils adjacent to the locations of root specimens correspondingly labelled A to E in Fig. 1.

A. Ambrose clay loam	
0 to 8 inches	Grayish-brown clay loam
8 to 24 inches	Grayish-brown silty clay, moderately compact
24 to 32 inches	Brown clay, very compact
32 ins. and below	Mixed brown and light-brown clay, friable
B. Ambrose silty clay loam	
0 to 24 inches	Dark grayish-brown silty clay loam
24 to 48 inches	Dark-brown silty clay loam, very compact
48 ins. and below	Brown to light-brown clay, slightly compact
C. Botella loam	
0 to 26 inches	Brown loam
26 to 34 inches	Brown clay, moderately compact
34 ins. and below	Brown clay, very compact
D. Altamont silt loam	
0 to 15 inches	Brown silt loam
15 to 30 inches	Light-brown silt loam, slightly calcareous
30 to 48 inches	Brown clay, very calcareous, lime in seams
48 ins. and below	Light-brown friable clay, very calcareous, lime in seams
E. Ambrose clay loam	
0 to 12 inches	Dark brown clay loam
12 to 30 inches	Very dark brown to black silty clay loam, slightly compact
30 to 48 inches	Light brown silty clay, very compact
48 ins. and below	Brown to light-brown friable clay loam
F. Tierra clay	
0 to 18 inches	Very dark grayish-brown clay, very compact
18 to 32 inches	Mixed grayish-brown and light-brown silty clay loam, moderately compact
32 ins. and below	Semi-consolidated substratum (marine shale)

Terracing modified the natural soil profiles, forming artificial soil profiles on part of the terraced area. The amount of such modification, which is the combined function of the terrace type and the degree of slope, may be defined, in a single valued manner, as the extent to which subsoil, or lower soil horizon, is exposed on the surface of the terrace bench. On a given slope such exposure would be least in the case of the level-basin terrace, of intermediate extent in the Reddick and Javanese terraces, and most extensive in the preformed terrace. Within the limits of slope for the types of terraces described in this paper, the degree of modification for a given type is a function of the sine of the angle of slope.

Materials and Methods

One-year-old Mexicola (*Persea drymifolia*) seedlings propagated in gallon containers were planted in April and May 1939. Shortly after planting time, the space immediately adjacent to the plants was heavily mulched with barley straw. Coincidently, bare areas on the terraces received a light application of barley straw. In the fall of 1939 the benches of the Reddick, Javanese, and preformed terraces were deep-tilled (subsoiled) to a depth of 16 inches, a minimum distance of 3 feet from nearest subsoil furrow to tree trunk being maintained. In March 1940 a heavy cover crop on the benches of these same terraces was turned under by disc-harrowing, and they were clean cultivated during the following summer. Other parts of the terraced areas were not cultivated in 1940, except that summer weeds were hoed down on the risers. Unusually heavy precipitation in the winter of 1940–41 developed a dense volunteer winter ground cover that was growing rank on most of the terraced area at the time root examinations were started.

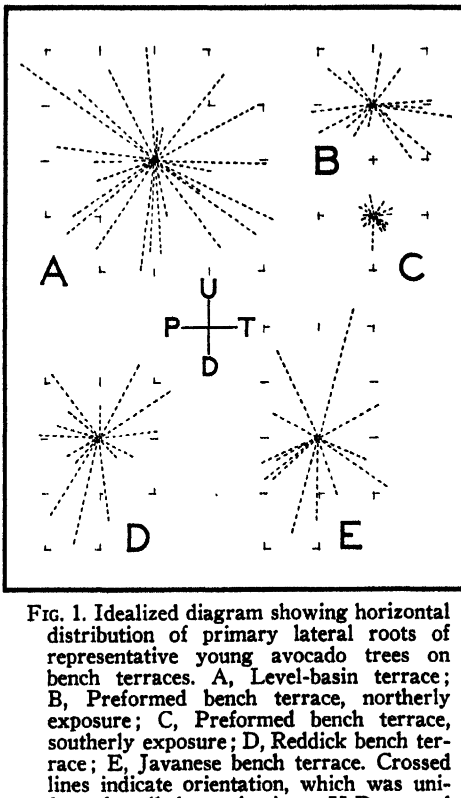

Fig. 1. Idealized diagram showing horizontal distribution of primary lateral roots of representative young avocado trees on bench terraces. A, Level-basin terrace; B, Preformed bench terrace, northerly exposure; C, Preformed bench terrace, southerly exposure; D, Reddick bench terrace; E, Javanese bench terrace. Crossed lines indicate orientation, which was uniform for all the projections; U-D, up and down hill; P-T, parallel to the edge of the terrace. Intervals are spaced at 2 feet.

Water from a tank-wagon supply was added to the soil of all of the plants in the summer of 1939 and to that of most of the plants in the summer of 1940. The amount of water added is tabulated below. Precipitation was above normal during the experimental period.

	Water Added to Soil of Each Plant (Liters)	
	Summer 1939	Summer 1940
Reddick bench terraces	53	27
Level-basin terraces	61	None
Preformed terraces, northerly exposure	61	45
Preformed terraces, southerly exposure	68	45
Javanese terrace	61	27

Top development of trees was measured, and their general condition was evaluated with respect to the several soils, exposures, and terrace types in January 1941. In the period February to May 1941, roots of the avocado trees were excavated for examination. Three methods were used in these excavations: (a) A circular trench was dug around the plant at a distance from the tree trunk greater than the maximum lateral root length; the trench was then gradually advanced inward, the roots being exposed by removing the enclosing soil with a sharp-pointed tool. (b) Linear trenches were dug in certain directions with respect to the tree axis and the axes of the terraces, the root distribution being examined in the walls of these trenches. This method is similar to the bisect method of root examination described and extensively utilized by Weaver (16, 17, 18) and his co-workers in the study of the roots of grasses and field and vegetable crops. (c) To supplement the information gained by the two previous methods, two trenches intersecting at right angles were dug at certain tree locations to determine the lateral root spread up and down the hill and along the terrace contour.

Results

Top Growth:—Top growth of the young avocado trees on the several bench terraces is summarized in Table I. It will be noted that

TABLE I—Summary of Top Growth of Young Avocado Trees on Bench Terraces at San Juan Capistrano, California*

Soil	Type of Terrace	Exposure	Average Height (Feet)	Average† Diameter (Inches)	Relative Growth Index	Condition of Trees
Tierra clay	Preformed	Southerly	2.1	11/16	0.9	Very poor
Ambrose clay loam	Preformed	Southerly	2.7	10/16	1.0	Poor
Botella clay loam	Preformed	Southerly	3.1	12/16	1.4	Fair
Ambrose clay	Reddick	Southerly	3.1	14/16	1.7	Very good
Botella loam	Preformed	Southerly	3.7	14/16	2.0	Fair
Altamont silt loam	Reddick	Southerly	3.9	19/16	2.8	Excellent
Ambrose silty clay loam	Preformed	Northerly	4.2	18/16	2.9	Good
Ambrose clay loam	Javanese	Northerly	5.1	18/16	3.6	Excellent
Ambrose clay loam	Level-basin	Southerly	4.8	30/16	3.8	Very good
Ambrose clay loam	Level-basin	Northerly	6.7	28/16	7.3	Very good

*Growth measurements made January 6, 1941. Conditions of trees evaluated January 16, 1941.
†Diameters were measured at a point 1 inch above ground surface.

there are divergences in this table between the rank determined by the growth index and that determined by the condition of the trees. These are explained in the paragraphs below.

Root Development, General:—The root system of the avocado investigated in this study consists, in its major elements, of an imperfect taproot and the primary lateral roots that issue from it. A short distance from the surface, generally from 6 inches to 1 foot, the taproot divides into branches, which may bend to assume a lateral position. The primary lateral roots divide, mainly by forked branching, into secondary lateral roots. A fourth order of roots branch at a high angle from the secondary lateral roots; these may be called tertiary lateral roots. The fine roots prevalent in the upper layer of the soil under some conditions are secondary and tertiary lateral roots. With the exception of the development of fine near-surface roots, the root habit was essentially the same on all four types of terraces.

The avocado roots are spotty in distribution. Large sections of ground around trees that made vigorous growth showed no roots. This spottiness in root distribution appears to be a genetic characteristic as it occurred under all conditions of growth.

Maximum root penetration was slightly over 5 feet in a soil represented by profile D (see section on "The Soils"). This maximum penetration was on a Reddick bench terrace on a southerly exposure. Maximum lateral root spread of 8 feet, measured radially from the tree trunk, took place in Ambrose silty clay loam on a level-basin terrace on a northerly exposure. Profile E is representative of the soil in which maximum root spread occurred.

The heavier soils caused a reduction in the number, and an increase in the size, of roots that did develop. Conversely, lighter soils caused an increase in the total number of roots and favored the development of finer roots. Frequently, a primary lateral root, on entering a soft, permeable soil zone, subdivided into many fine secondary lateral roots. Roots were found sparingly or not at all in poorly aerated compact soil zones in which soil moisture and other conditions were favorable for growth. A high level of soil aeration appears to be as essential for vigorous root growth as adequate soil moisture.

Root Development on Preformed Terraces; South Exposure:—Root growth on the heavy soils on this exposure (Tierra clay and Ambrose clay loam) was extremely poor. In many instances they were restricted entirely to the column of soil, about a foot in diameter, formed by the fill-back soil in the hole dug to receive the plant at planting time. Downward penetration, below the initial depth of planting, was nil in some specimens and did not exceed 6 inches in any instance. Top development was characterized by a spindling trunk, elongated unduly with respect to its diameter.

Root growth on Botella clay loam and Botella loam was considerably better than that in Tierra and Ambrose clays. Here again, the top growth was characterized by a spindling trunk. The group of plants on the Botella loam have a slightly higher growth index than those on the Ambrose clay or Reddick terraces (cf. lines 4 and 5, Table I). The plants on these Reddick terraces were in a much healthier condition all through the experiment, although averaging less in height, than those in Botella loam on the preformed terraces.

Root growth was so limited on south-facing preformed terraces that terrace shape could have exerted only a small effect on root distribution. In some specimens roots were more numerous in the section of ground parallel to terrace edge. This section was occupied by filled soil that, in some instances, was more favorable for root development than adjoining ground on the terrace bench and on the terrace riser.

In general, the effect of preformed bench terraces on this southerly slope was to make an initially poor site worse.

Root Development on Preformed Terraces; North Exposure:—Root growth on the Ambrose silty clay loam on the northerly preformed terraces was fair. Penetration, measured from the surface of the bench, ranged from 1½ to 4 feet. Lateral spread, measured from the trunk, ranged up to 3 feet. There was a slight development of fine

near-surface roots on the mulched terrace risers and on the mulched areas on the terrace benches in the immediate vicinity of the plant.

There was a definite tendency for the roots on these northerly preformed terraces to be larger in number and size in the soil sectors parallel to the edge of the terrace. Individual specimens showed much variation in horizontal distribution, however. In some, the primary lateral roots were larger in size and number on the uphill side, in others, the roots were larger and more numerous on the downhill side. Viewed in transverse profile (vertical section at right angle to terrace edge), primary lateral roots seemed little affected by the terrace shape.

Indications in the fall of 1940 were that the avocados on northerly preformed terraces were being adversely affected by soil changes induced by this type of terracing. Their condition was inferior at that time to those on the same slope and in similar soils on level-basin and Javanese terraces. It seems probable that this adverse effect would have become more pronounced as the trees became larger.

Root Development on Javanese Bench Terrace:—Roots grew well in Ambrose clay loam (see profile E in section on "The Soils") on the Javanese bench terrace (northerly exposure). Measured from the terrace bench, root penetration ranged up to 4 feet. Lateral root spread from the trunk ranged up to 5 feet. Primary lateral roots were most numerous on the downhill side; a moderate development of fine near-surface roots was also found on this side. This preponderance of primary lateral roots on the downhill side may be ascribed to the fact that in constructing the terrace, topsoil is concentrated in this region. Development of fine near-surface roots resulted from the conservation of surface moisture by mulch.

The trees on the Javanese bench terrace were in excellent condition when evaluated. This condition, somewhat superior to that of nearby trees on level-basin terraces in similar soil, is believed accounted for by the favorable drainage qualities of the Javanese bench terrace.

When viewed in transverse profile, upper primary roots conformed in vertical distribution to the profile of the terrace. Such roots on the bench side were approximately horizontal; on the riser side (downhill) they dipped at an angle roughly corresponding to the dip of the surface of the terrace riser.

Root Development on Reddick Bench Terraces:—On these southerly Reddick bench terraces root growth was fair to good in Ambrose clay and excellent in Altamont silt loam. In the silt loam, root penetration ranged up to 5 feet, as measured from the bench surface adjacent to the tree; lateral root spread ranged up to 5 feet from the tree trunk. Root penetration in the Ambrose clay was slightly less than in silt loam, but root spread was considerably less, being in the main less than 3 feet. Systems in clay averaged fewer roots and a smaller proportion of finer primary and secondary roots than those in silt loam.

A layer of mulch to a depth of from 1 to 3 inches had accumulated on the terrace risers by the winter of 1940–41. Under this, fine near-surface roots were found to a slight extent in the clay and to a moderate extent in the silt loam. No fine near-surface roots were found on the bench portions of the terraces and none were expected, as these

portions of the terraces had undergone clean cultivation in 1940.

Upper primary roots on the riser side of the terraces conformed in distribution, as seen in transverse profile, to the dip of the riser surface. On the bench portions no correlation was observed between vertical distribution of primary roots and the attitude of the bench. In some specimens there was a tendency for roots to be more numerous in the zone parallel to the edge of the terrace. On the whole, however, no definite correlation could be shown between horizontal distribution of the main lateral roots and terrace shape.

Top growth of trees on Reddick bench terraces was closely correlated with root development. When top evaluation was made trees on Reddick terraces were in better condition than might have been expected. As in the case of trees on the Javanese terraces, this is believed to be the result of favorable drainage.

Root Development on Level-Basin Terraces:—On the level-basin terraces root growth was excellent. Although exhibiting characteristic spottiness, previously discussed, roots were fairly well distributed horizontally and vertically. The average lateral spread of roots on these level-basin terraces was greatest for any of the terrace types studies. Within this group, root and top growth were found to be substantially larger on the northerly than on the southerly terraces. On the southerly terraces, spread of the primary lateral roots was, in the main, less than 5 feet; on the northerly terraces, it was, on the average, greater than 6 feet. Average penetration of roots on the southerly terraces was slightly less than on the northerly terraces. Top growth on the two exposures correlated closely with root growth.

On the downhill side there was a slight but noticeable preponderance of roots, in comparison with those on the uphill side. The soil in the shallow layer of the downhill side was composed entirely of topsoil, part *in situ* and part filled in by soil moved from the upper side. This change in the soil layering, inherent in the terrace, accounts for the eccentricity in root distribution.

A mulch layer about 2 inches deep on the southerly terraces and ranging up to 4 inches deep on the northerly terraces, had accumulated in the basin by the winter of 1940–41. Under this layer a dense accumulation of fine near-surface roots was found on the northerly terraces. Development of these fine roots was less extensive under the mulch of the southerly terraces. Distribution of these fine roots was not confined to the soil proper; many lay on the surface of the soil and some extended upward into the mulch.

During wet weather, water is impounded in the basins of these terraces, thereby impairing the aeration of the soil. This factor resulted in a depression of the trees on level-basin terraces in the winter of 1940–41. Thus the trees are rated in Table I as being in a very good, rather than in an excellent condition. This depression was temporary, and, with the advent of dry weather, an excellent top-growth condition reappeared.

Discussion

The Tierra and Ambrose soils involved in this study have a genesis similar to some of the soils of commercial avocado groves on which

mature avocado trees declined and died in large numbers after the unusually wet winter of 1940–41. The most notable feature of these soils is their low infiltration rate, a factor that results in soil drowning in exceptionally wet weather or when heavily irrigated.

It should be borne in mind that the avocado trees in this experiment were grown under essentially dry-land conditions. Most avocado trees grown in California, and practically all of those grown commercially, are supplied with irrigation water.

The circular trench section appears to be the best method of uncovering the roots of the avocado for study. Because of the spottiness of avocado roots, the bisect method is not well adapted for this study. In detailed studies of fine near-surface root development in the avocado, hydraulic methods of root excavation may be indicated.

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Carbohydrate Changes in the Date Palm During the Summer[1]

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Fig. 1. Palm of Hayany variety, similar to those of that variety used for analysis. The white horizontal markers on the trunk indicate locations where "bottom trunk" (BT), "trunk by lower leaves" (TLL), and "trunk below bud" (TBB) samples were taken.

PROBLEMS in offshoot propagation, palm transplanting, leaf removal and fruit thinning in commercial date growing have for some time required information upon the extent of accumulation of carbohydrate reserves in the date palm (*Phoenix dactylifera*). The trunk of the sago palm (*Metroxylon sagus*) in India (4), contains several hundred pounds of starch, provided the palm is cut before flowering. *Ph. pusilla* is used by natives of Ceylon as a source of starch (4). The commercial tapping of the wild date palm (*Ph. sylvestris*) in the top part of trunk produces sap high in sugar (4). With only this background, a study of the commercial date palm was started in 1939, to determine (a) the approximate amounts of carbohydrate fractions in different parts of the palm, (b) the changes in amounts of carbohydrate during the summer, and (c) the effects of fruiting upon any changes in amounts of carbohydrates during the summer.

[1]This study is a part of the cooperative research program by the Office of Indian Affairs, U. S. Department of the Interior, and the Bureau of Plant Industry, U. S. Department of Agriculture.

The writers appreciate the assistance of G. H. Leach and William Dollins in digging out and cutting up the palms, of C. L. Crawford in preserving and drying the samples, and of D. C. Moore in taking the photographs.

Materials and Methods

Eight palms of the Hayany variety at the United States Date Garden and eight of the M'Kentisha Degla variety at the experimental garden on the Martinez Indian Reservation were available. The Hayany palms were 23 years old with trunks about 24 feet high; the M'Kentisha Degla were 17 years old, with trunks about 12 feet high. The palms were somewhat variable in size and vigor, but it was possible to select pairs of the same size and apparent vigor. In April all the fruit bunches were removed from one palm in each pair, with the remaining palm left with all (from 12 to 15) bunches unthinned. This provided four "non-fruiting" and four "fruiting" palms of each variety. It was hoped that a comparison of the carbohydrate levels in the individual palms in each pair would show the relation of stored carbohydrates to fruit development.

A palm representative of the Hayany used is shown in Fig. 1, and a close-up of the top of a felled palm during sampling is shown in Fig. 2.

As soon as each palm was down, the following samples were collected: "Bottom Trunk" (see B T Fig. 1); "Trunk by Lower Leaves" (see T L L in Figs. 1 and 2-B); "Trunk Below Bud" (see T B B in Figs. 1 and 2-B); "Lower Leaf Bases" (see L L B in Fig. 2-A); and "Medium-sized Roots".

Each trunk sample was composed of material from one location in the center of the trunk. The "lower leaf bases" sample was a composite of the material from the center of the bases of the 10 lowest (1937) leaves on which all pinnae were still green. All but the root samples were covered with cold alcohol, subsequently boiled for 10 minutes, within 1 to 4 hours after collection. The root samples were

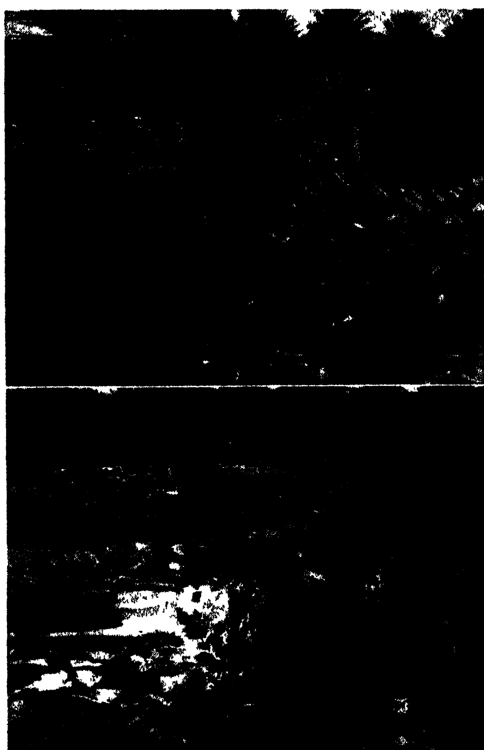

FIG. 2. Top of palm, before (A) and after (B) removing all leaves. A, The centers of the bases at LLB of 10 leaves made up "lower leaf bases" sample. B, The center of the trunk at TLL provided "trunk by lower leaves" sample, and the center of the trunk at TBB provided the "trunk below bud" sample.

dried at 70 degrees C with partial vacuum.

Sugars were extracted from the dry residue with approximately 80 per cent alcohol, and determined by Bertrand's modification of the Munson Walker method, according to A.O.A.C. (2). "Starch" was determined by autoclaving sugar free residue at 15 pounds for 15 minutes, digesting with "Pangestin", precipitating pectic substances by bringing mixture to an alcohol concentration of 60 per cent, and then hydrolyzing alcohol-free filtrate according to A.O.A.C. (2). Barr's (3) method of extracting "dextrin-like" fractions from sugar free residue with 10 per cent alcohol and with hot water showed the alcohol-soluble fraction to have an invert sugar value of 2 to 4 per cent on dry weight basis and hot-water soluble fraction to be very small or lacking.

Since values for "starch" minus "dextrin-like" substances were usually much greater than values for "dextrin-like" substances for the samples fractioned, the invert sugar values obtained by the starch procedure, which include dextrins, will for simplicity be referred to as "starch". "Total acid-hydrolyzable polysaccharides" were obtained by hydrolyzing the sugar-free residue with 10 per cent HCl (sp.gr. = 1.125) on a boiling water bath for 2½ hours. Reducing sugars are expressed as "invert sugar and sucrose"; and total sugars, starch, and acid-hydrolyzable polysaccharides as "invert sugar", as in Reference Table 43 of A. O. A. S. (2). "Non-hydrolyzable residue" was calculated by subtracting the sum of "total sugar" and "total acid-hydrolyzable polysaccharides" from the total dry weight.

TABLE I—Water and Carbohydrates in Different Locations of Two Hayany Date Palms on June 2, 1940

Location		Water* (Per Cent)	Carbohydrates†					
			Reducing Sugars (Per Cent)	Sucrose (Per Cent)	Total Sugars (Per Cent)	Starch (Per Cent)	Acid-Hydrolyzable Polysaccharides Minus Starch (Per Cent)	Non-Hydrolyzable Residue (Per Cent)
Lower Leaf Bases	F§	76.4	6.8	5.7	12.5	0.5	19.7	67.3
	N-F	75.5	11.4	7.4	18.8	2.2	17.4	61.6
Trunk Below Bud	F	71.4	1.6	12.4	14.0	17.1	17.0	51.9
	N-F	71.1	1.6	10.0	11.6	21.9	16.3	50.2
Trunk by Lower Leaves	F	56.0	0.2	7.7	7.9	35.3	19.4	37.4
	N-F	59.1	0.3	7.3	7.6	39.6	16.0	36.8
Bottom Trunk	F	51.5	0.0‡	9.3	9.3	42.0	15.7	33.0
	N-F	54.8	0.0‡	10.6	10.6	44.3	15.5	29.6
Roots	F	66.5	0.4	0.1	0.5	0.7	13.9	84.9
	N-F	70.0	0.4	0.2	0.6	0.7	11.8	86.9

*Water expressed as percentage of fresh weight.
†Carbohydrates expressed as reducing sugars in percentage of total oven-dry weight.
‡Titration for reducing power only 0.1 milliliter above blank.
§F = fruiting N-F = non-fruiting.

Distribution of Carbohydrates in the Palm

The amount and distribution of water and carbohydrate fractions in a date palm are indicated by the analyses of Hayany palms on June 2, given in Table I.

Samples from both "fruiting" and "non-fruiting" palms are presented to illustrate the variation observed between single samples from duplicate palms. (As early as June 2, the differences in all but leaf bases are not considered to be appreciably influenced by the crop in the "fruiting" palms.)

The higher reducing sugar than sucrose in the "lower leaf bases" is in contrast to the predominance of sucrose in the trunk. The high starch content of the trunk in contrast to the low starch content of the leaf bases and roots, indicates that the trunk serves as a region of carbohydrate storage. On the assumption that one of these Hayany trunks, exclusive of the dead leaf bases, had a dry weight of only 1000 pounds, the trunk on June 2, would contain about 400 pounds of starch.

Changes in Amounts of Carbohydrates During the Summer

The relation of the date of taking samples to the stage of development of the fruit is shown in Fig. 3. Hayany fruits, which ripen (with a

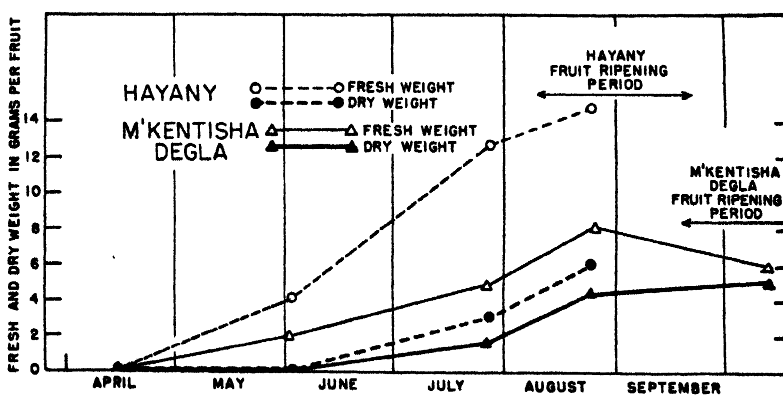

Fig. 3. Fresh weight and dry weight per fruit for Hayany and for M'Kentisha Degla, based on fruit samples taken at end of flowering period and subsequently on dates of collecting palm samples.

high water content) during late August and early September, accumulated about 50 per cent of their total dry matter (mostly sugars) just preceding or during ripening. M'Kentisha Degla fruits, also accumulated about 50 per cent of their total dry matter during the same period, but ripened (with the usual relatively great dehydration) about a month later. Thus during August occurred for both varieties the highest rate of use of carbohydrates for increasing sugar content of fruit.

Changes during the summer in the amounts of total sugar, starch and acid-hydrolyzable polysaccharides minus starch in the fruiting palms of both varieties are illustrated by the analyses of the "trunk

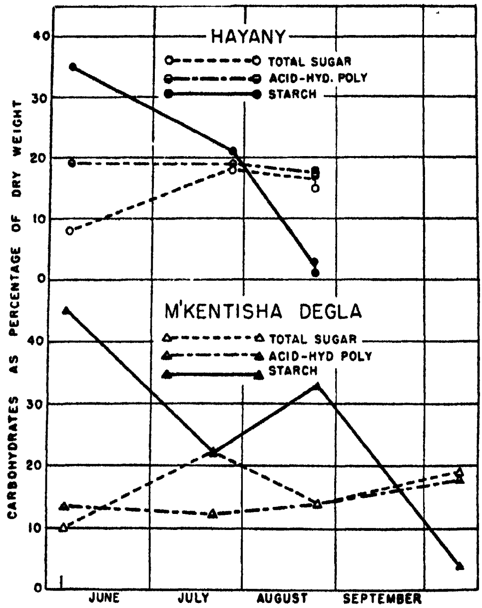

FIG. 4. Changes during the summer in total sugar, starch and acid-hydrolyzable polysaccharides minus starch, in trunk by lower leaves of fruiting palms of Hayany and M'Kentisha Degla, expressed as percentage of dry weight.

by lower leaves" samples presented in Fig. 4. Outstanding is the change from very high starch content in the trunk in early summer to extremely low starch content during the period of fruit ripening, with the most rapid starch depletion just preceding or during the period of fruit ripening. It seems noteworthy that with M'Kentisha Degla the period of most rapid starch depletion did not occur during the most rapid increase in sugar content of the fruit. This suggests that carbohydrate reserves in the palm may be utilized in greater amounts by the process of fruit ripening than by the process of sugar accumulation in the fruit. Greatly increased rate of fruit respiration during ripening might be largely responsible for this relatively great carbohydrate use, since Magness and Ballard (7) found that the respiration of detached

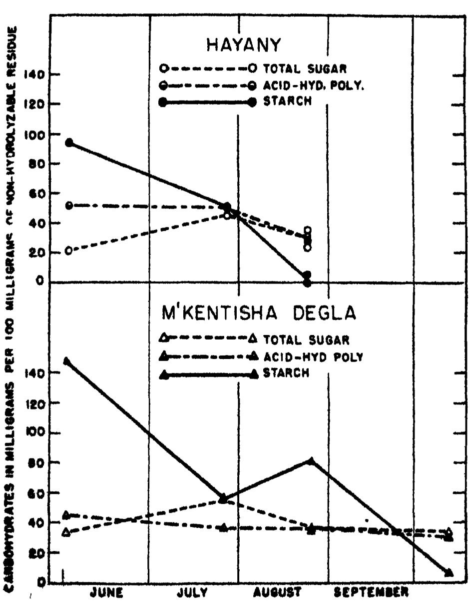

FIG. 5. Changes during the summer in total sugar, starch and acid-hydrolyzable polysaccharides minus starch in "trunk by lower leaves" of fruiting palms of Hayany and M'Kentisha Degla, expressed as milligrams per 100 milligrams of non-hydrolyzable residue.

pear fruits at 60 degrees F became four to five times greater as the fruits increased in ripeness.

Since the depletion in starch in late summer is usually not accompanied by an equivalent increase in other carbohydrate fractions, and is presumably used elsewhere than in the trunk, this large reduction in percentage starch probably means a reduction in the proportion of total dry matter to total sugar. This would increase numerically the percentage of total sugars in late summer when no actual increase in sugars per unit volume had occurred. Expressing the results as amount per unit volume of plant material would be desirable, but it had not been feasible to collect trunk samples of known volume. On the assumption that the non-hydrolyzable residue was composed of cellulose and other relatively constant carbohydrates, this fraction was tried as a basis for expressing carbohydrate content.

The carbohydrates, expressed as percentage of total dry matter in Fig. 4, are shown in Fig. 5, expressed as milligrams per 100 milligrams of non-hydrolyzable residue. A comparison of Figs. 4 and 5 shows no appreciable difference in the starch changes; but where Fig. 4 shows a slight increase in total sugar for M'Kentisha Degla during September, Fig. 5 shows little change in total sugar. Although this method in Fig. 5, of relating total sugar and starch to non-hydrolyzable residue would be misleading if non-hydrolyzable residue changed appreciably, it seems preferable to the use of total dry matter and is used hereafter for comparison of total sugar and starch changes in non-fruiting with such changes in fruiting palms.

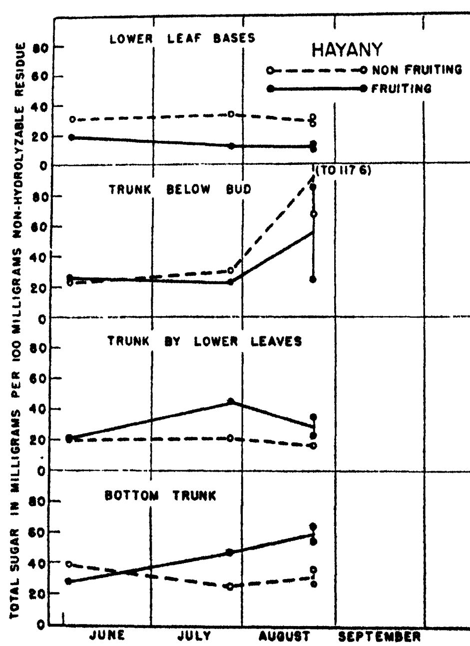

FIG. 6. Comparison of fruiting with non-fruiting palms of Hayany, in relation to total sugar expressed in milligrams per 100 milligrams of non-hydrolyzable residue.

Effects of Fruiting Upon Total Sugar and Starch Changes During the Summer

To distinguish the effects of fruiting from the effects of environmental conditions, the changes in total sugar and starch in fruiting palms are compared with the changes in non-fruiting palms. Total sugars in both Hayany (see Fig. 6) and M'Kentisha Degla (see Fig. 7) tended to be higher in the trunks of fruiting than in the

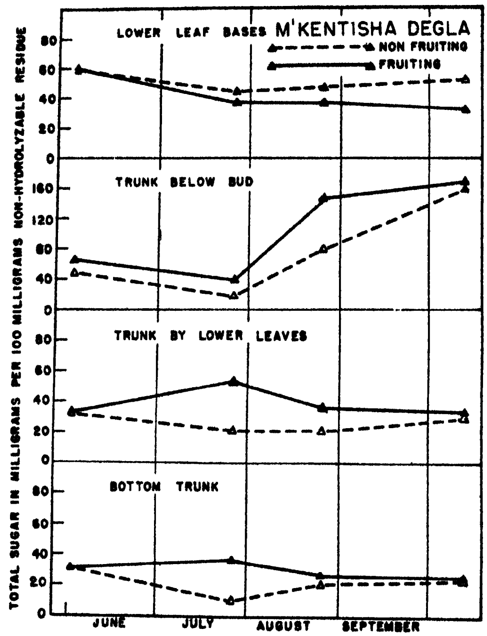

FIG. 7. Comparison of fruiting with non-fruiting palms of M'Kentisha Degla, in relation to total sugar expressed in milligrams per 100 milligrams of non-hydrolyzable residue.

trunks of non-fruiting palms, except in the "trunk below bud" of Hayany. This higher total sugar in the fruiting than in the non-fruiting palms did not become evident in the "trunk by lower leaves" and "bottom trunk" locations until the second sampling, in late July. This is the approximate time during the summer when Aldrich and Crawford (1) found the seed had attained maximum size and dry weight, and at which the marked acceleration in dry matter accumulation of pulp was just starting. It is possible that at this stage the seed may produce some substance which stimulates sugar accumulation in the trunk and in the fruit.

The lower total sugar content in the leaf bases of the fruiting than of the non-fruiting palms suggests that the sugar accumulation in the trunk and in the fruit of the fruiting palm was accompanied by a greater sugar

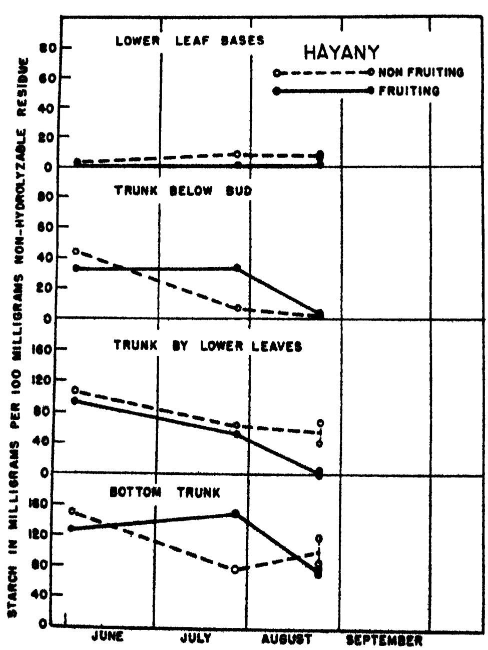

FIG. 8. Comparison of fruiting with non-fruiting palms of Hayany, in relation to starch expersseḋ in milligrams per 100 milligrams of non-hydrolyzable residue.

movement out of the leaves than occurred for the non-fruiting palms. However, the marked increase in total sugar in the "trunk below bud" samples in the non-fruiting as well as in fruiting palms suggests that some influence other than that from developing fruits is effective in causing sugar accumulation in this location.

The marked starch depletion in "trunk by lower leaves" samples of the fruiting palms during fruit ripening, already mentioned, seems related to fruiting, since in this location no depletion at this time is shown in the non-fruiting palms (see Figs. 8 and 9). However, in the "trunk below bud" and "bottom trunk" samples of Hayany, starch at the end of August is as low in non-fruiting as in fruiting. The "trunk below bud" samples of M'Kentisha Degla show a slightly lower starch content for fruiting than for non-fruiting. The "bottom trunk" samples for M'Kentisha Degla show complete depletion of starch for the fruiting palm, but, in contrast to Hayany, show a marked increase in starch in the non-fruiting palms, beginning in August. No explanation is evident.

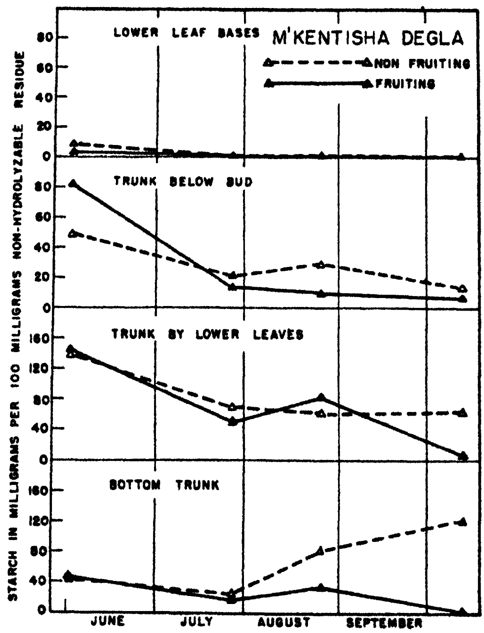

FIG. 9. Comparison of fruiting with non-fruiting palms of M'Kentisha Degla, in relation to starch expressed in milligrams per 100 milligrams of non-hydrolyzable residue.

With the exception of the M'Kentisha Degla "bottom trunk" sample for the non-fruiting palms (11 out of 12 series of samples, or 3 out of 4 series of palms) all trunk samples in non-fruiting as well as in fruiting palms show a trend for starch content to decrease during the summer. This starch decrease during the summer probably corresponds to the summer decrease in acid-hydrolyzable carbohydrates observed in the holm oak (*Quercus ilex*) and Austrian pine in 1906 by Sablon (8) who suggested that in some evergreens carbohydrate reserves decrease during the summer because at that time respiration exceeds "assimilation". Cameron (5) with 3½-year-old orange trees and Cameron and Borst (6) with 6-year-old avocado trees likewise found that starch decreased during the summer, with Cameron (5) offering the same explanation as Sablon.

Practical Implications of Results

The high starch content of the palm trunk in early summer, followed by a trend for starch decrease during June and July, in non-fruiting palms indicates that during the hot summer weather the respiration of leaves and trunk, and the growth of roots, leaves (leaf growth is about constant during the June-October period) and trunk draw upon the reserve carbohydrates. This suggests, but does not demonstrate, that carbohydrate reserves in trunk at the beginning of summer are essential for subsequent normal palm growth. The depletion of starch in the "trunk by lower leaves" samples of fruiting palms just preceding or during fruit ripening indicates that during ripening a heavy crop draws upon the remaining reserve carbohydrates. Therefore, if carbohydrate reserves were relatively low at the beginning of the summer, the normal carbohydrate use for palm growth during the summer might reduce the supply of reserve carbohydrates to such an extent that a limitation of them during fruit ripening would result in poor fruit quality.

With carbohydrate reserves tending to decrease during the June to August or September period, apparently because photosynthesis is less than utilization, it follows that during the October to May period photosynthesis must exceed utilization. Since the amount of carbohydrates assimilated is directly related to amount of leaf area, maximum photosynthesis and maximum accumulation of carbohydrate reserves would be expected when all green leaves are left on the palm during this fall-winter-spring period. On this basis, when the removal of lower leaves is necessary to reduce fruit scarring and permit bagging of bunches, such leaf removal should not be in the fall but should be as late in the spring as possible.

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Nitrogen Uptake by Grapefruit Trees in the Salt River Valley[1]

By R. H. Hilgeman, *University of Arizona, Tucson, Ariz.*

FERTILIZATION studies, (1) and studies of quality and yield (3) of grapefruit in Arizona indicate that nitrogen plays an important role in regulating fruitfulness of the trees. This influence of nitrogen has emphasized the need for information on such points as: the rate of uptake of nitrogen from various fertilizers; the rate of uptake of nitrogen at different seasons; the effect of soil character and age of tree upon the uptake of nitrogen; and the relation of fertilizer practice to seasonal nitrogen content.

Preliminary studies (2) in 1938–1939 indicated that nitrogen is taken up rapidly, particularly from the nitrate form of fertilizer, and that response is related to the existing nitrogen level in the tree.

Materials and Procedure

These studies were conducted cooperatively in two privately owned groves which had not been fertilized for several years. In both groves the trees were reasonably vigorous, and uniform, but at a medium low nitrogen level. Grove A was comprised of trees 28 years old, growing in Cajon gravelly loam soil. Irrigation water used in this grove contained from 1 to 2 parts per million nitrates. The trees in Grove B were 12 years old, growing in a soil classified as Mohave gravelly sandy loam calcareous phase. Its irrigation water contained from 11 to 24 parts per million nitrates. Both groves had excellent drainage. Due to a water shortage, irrigations were curtailed during the summer of 1940 and the trees wilted between irrigations in Grove B.

The following fertilizers were applied to plots consisting of five adjacent trees: 6½ pounds of calcium nitrate to each tree; 5 pounds ammonium sulfate to each tree; 2¼ pounds of urea to each tree; and 200 pounds steer manure to each tree. A control plot was not fertilized. One such complete series was set up in each grove in August, in December, and in February (Grove B in March).

The nitrogen content of the leaves was used as an index of the nitrogen level in the tree. A total of 20 leaves, selected equally from the north, south, east, and west sides of each tree at about 5 feet above the ground were obtained at each sampling date. This made a total of 100 leaves per sample. The leaves were placed in an air-tight container, carried to the laboratory and weighed. After drying at 70 degrees C, total nitrogen was determined by the Gunning (4) method. The results were calculated as per cent nitrogen on a dry weight basis, per cent nitrogen on a fresh weight basis, and total nitrogen per leaf. These data were interpreted from graphs of each treatment.

After February 1 three replicates of the control were present in each grove. Before differential treatments were started all plots were sampled. Ninety samples of these replicates had an average probable

[1]The writer wishes to acknowledge the assistance of J. G. Smith, G. E. Draper, and R. Keswick.

error of the mean of ± .014 per cent nitrogen on a fresh weight basis and ± .038 per cent on a dry weight basis. Duplicate samples of the same plot varied within lesser limits with a probable error of the mean of ± .009 per cent on a fresh weight basis and ± .025 per cent on a dry weight basis.

DATA AND INTERPRETATION

Seasonal Changes in Leaf Nitrogen Values:—Fig. 1 presents the average seasonal changes in leaf nitrogen values from three unferti-

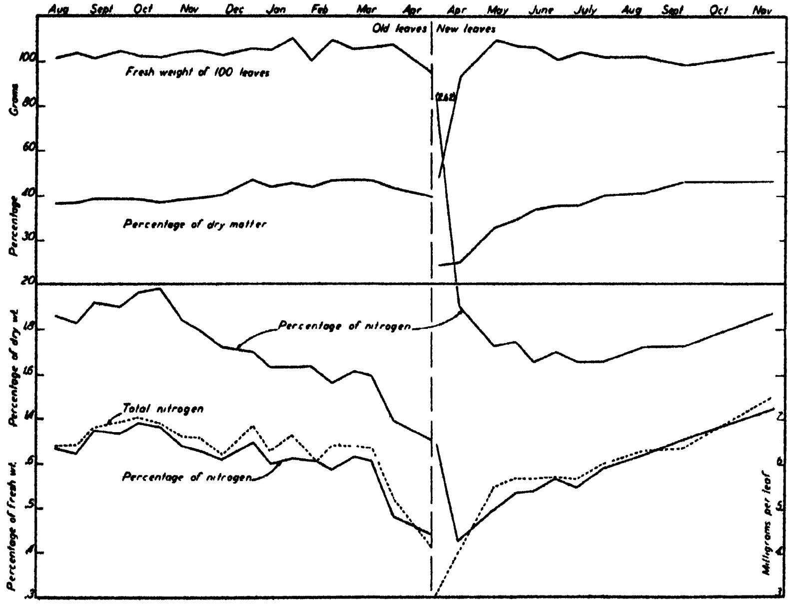

FIG. 1. Seasonal changes in leaf nitrogen values, fresh weight and percentage of dry matter.

lized plots in Grove A. It will be observed that seasonal changes influence the nitrogen values in the leaves. When the data are expressed as percentage of nitrogen on a dry weight basis, young leaves have a high percentage which decreases as the leaves become older. Between July and November the percentage increases, followed by a moderate decrease during the winter which culminates in a sharp decrease in late March just prior to full bloom. These values are not representative of the changes in total nitrogen per leaf at all times of the year. This is due to the gradual increase in the dry weight as shown by the percentage of dry matter trend.

The total amount of nitrogen per leaf increases rapidly in April and May followed by a gradual increase as the leaf becomes mature reaching its maximum in October and November. A gradual decrease takes place during the winter, followed by a sharp decline in late March. This decrease during the winter and spring is less than indicated by the dry

weight percentages due to the continued increase in the dry weight of the leaves during this period. Nitrogen per leaf values, however, are influenced by sampling technique as indicated by the values for fresh weight of leaves.

After April 15 the percentage of nitrogen on a fresh weight basis closely follows the total nitrogen per leaf. Because only slight differences in the percentage of dry matter existed between plots in the same grove on the same date, it also directly reflects differences between plots as shown by the percentage of nitrogen on a dry weight basis. Since percentage of nitrogen on a fresh weight basis eliminates errors in weight of leaf expressions, and presents a more accurate picture of nitrogen levels than the percentage based on the dry weight, it was selected as the method of expressing the experimental data.

Nitrogen Uptake at Different Seasons:—The experimental data obtained in Groves A and B are set forth in Figs. 2 and 3. It will be observed that the most evident results are the effects of commercial fertilizers applied at different seasons upon the nitrogen values in the new leaves during April and May. August fertilization induced a high nitrogen level during the fall and winter, but failed to produce a marked increase in the new leaves. The December series increased the nitrogen in the old leaves, and also caused an increase in the new leaves. February applications did not materially affect the old leaves, but

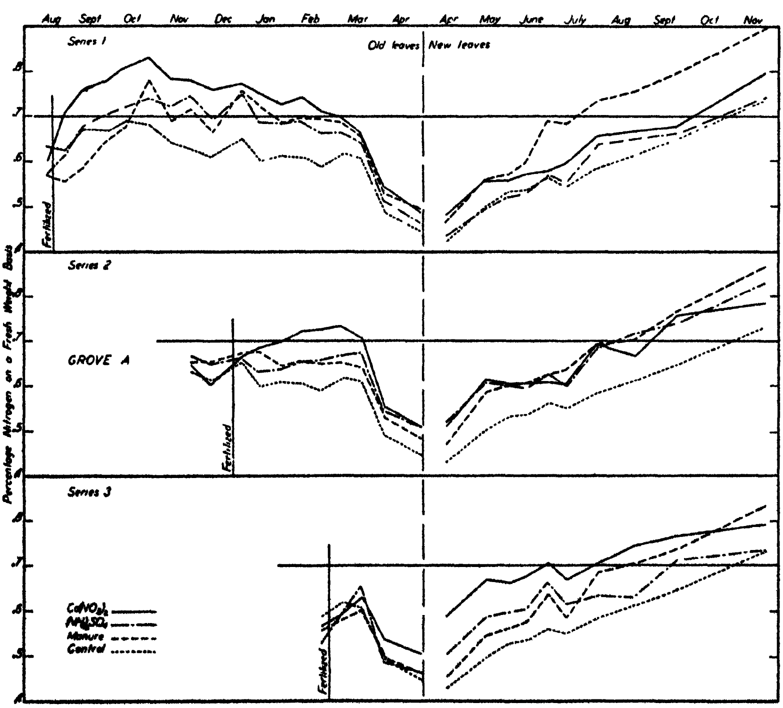

FIG. 2. Nitrogen uptake under the conditions of Grove A.

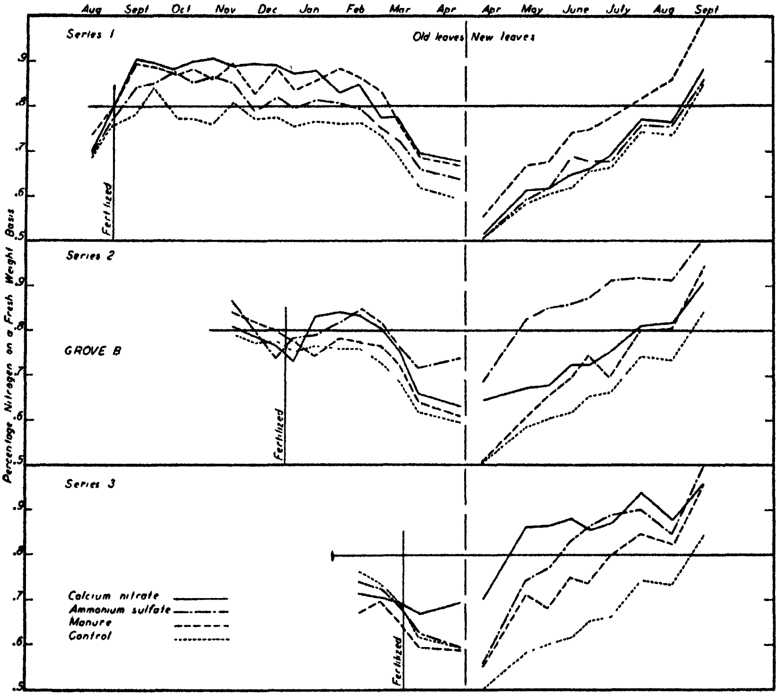

FIG. 3. Nitrogen uptake under the conditions of Grove B.

produced high nitrogen values in the new leaves. In general nitrogen was taken up more rapidly from all fertilizers during September and March than during January.

The nitrogen values of the leaves in the commercial fertilizer trials tended to decrease in relation to the control during the summer, while manure plots tended to increase.

Nitrogen Uptake from Calcium Nitrate:—The outstanding characteristic of fertilization with calcium nitrate is the rapid uptake of nitrogen and the comparatively short period over which the effect of the fertilization extends. The August series in both groves illustrates this situation. Nitrogen was taken up rapidly to a maximum point within 15 days in Grove B and 60 days in Grove A. A gradual decrease then occurred accelerating as the winter advanced. April analyses indicate that this fertilization produced no significant effect on the new leaves in Grove B and only slightly increased values in Grove A.

Uptake from the December series was at a lesser rate than in August, but carried over to produce a marked increase in the nitrogen levels in the new spring leaves. The highest nitrogen values in the new leaves were obtained from applications in February in Grove A and as late as March 17 in Grove B when the new leaves were about 15 per cent of full size.

The effect of the December and February fertilization carried over

into the summer. However, the wide differences evident in April between these plots became less as the summer advanced.

Nitrogen Uptake from Urea:—Urea was found to influence the nitrogen content of the leaves in a manner very similar to calcium nitrate, therefore this data was omitted from the charts. In the August series in Grove A, the urea and calcium nitrate trends and values practically coincided. Grove B coincided until April when the new leaves contained greater amounts of nitrogen than the calcium nitrate plots and maintained this difference during the summer.

The December series varied from the calcium nitrate trends in that rate of uptake was less rapid in both groves but the ultimate uptake was greater. Nitrogen values in the new leaves were higher than in the corresponding calcium nitrate plots. These higher levels were maintained throughout the summer.

In the February series in both groves the uptake from urea was again slower than from the calcium nitrate. In this instance the nitrogen values during the summer were lower.

It appears from these data that during midwinter nitrogen uptake from urea is at a slightly lesser rate than from calcium nitrate. The highest nitrogen level in the new spring leaves was obtained from the December fertilization.

Nitrogen Uptake from Ammonium Sulfate:—Nitrogen uptake from ammonium sulfate was more variable and less conclusive than from calcium nitrate. Under the conditions of Grove A the uptake at all times of the year was about one half that obtained from calcium nitrate, and at a slower rate. August applications did not significantly increase the nitrogen values of the new spring leaves. The December and February fertilizations increased the nitrogen content of the new leaves approximately the same as the December calcium nitrate application. Fertilization in December maintained a higher nitrogen level during the summer than either the August or February series.

Grove B differed somewhat from Grove A in its response to ammonium sulfate. Uptake was generally more rapid and winter applications had a more marked effect on the leaves in the summer. The August fertilization was very similar to Grove A. However, the December fertilization produced an increase in nitrogen equivalent to the calcium nitrate, and produced a high level in the new leaves, which was maintained during the summer. The March series did not differ significantly from the trends in Grove A.

Nitrogen Uptake from Manure:—The general characteristics of nitrogen uptake from manure are a low initial response, and a continued uptake over a long interval. Nitrogen values were still high in January 1941, 17 months after fertilization with manure.

In Grove A the August fertilization appeared to exert a starvation effect upon the tree during the first 30 days, after which a steady uptake of nitrogen occurred. Its effect upon the new leaves was more marked than the commercial fertilizers applied in August, particularly in the late summer when it attained higher values than any other plot. Fertilization in December and February only slightly increased the nitrogen in the old leaves and the new spring leaves. During the summer these

plots increased steadily in nitrogen to attain the highest levels in each series by November.

The response to manure was generally more rapid in Grove B. Immediate increases in nitrogen occurred from the August fertilization. This situation did not exist with the December and March applications which followed the trends of Grove A. All manure plots tended to increase in nitrogen during the summer at about the same level.

Summary

These studies suggest the following general situation. In diagnosing the condition of a tree by means of leaf analysis, the maturity of the leaf and the season of the year are of primary consideration. The percentage of nitrogen computed upon the fresh weight appears to present a more complete basis for comparisons than percentages of the dry weight. Nitrogen uptake from all fertilizers is more rapid in the spring and fall than in the winter. It, also, is more rapid in 12-year-old trees growing in light calcareous soil than in 28-year-old trees growing in loam soil. Nitrogen was taken up most rapidly from calcium nitrate followed by urea, ammonium sulfate and manure in order. The time of application of each fertilizer which produced the highest nitrogen value in the new leaves was February for calcium nitrate, December for urea and ammonium sulfate and August for manure. In the light calcareous soil (Grove B) approximately the same amounts of nitrogen were taken up by the new leaves from each commercial fertilizer when applied at the above dates. In the loam soil (Grove A) comparable amounts were taken up from calcium nitrate and urea, with a lesser amount from ammonium sulfate. Fertilization with manure is characterized by a low initial uptake and a prolonged period of response. Its effect upon new leaves in the spring is less marked than commercial fertilization during the winter, but induces a higher nitrogen level in the leaves during the summer and the following winter.

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Evaporation from a Shallow Black Pan Evaporimeter as an Index of Soil Moisture Extraction by Mature Citrus Trees

By J. O. REEVE and J. R. FURR, *U. S. Department of Agriculture, Pomona, Calif.*

SOIL moisture control in citrus orchards may be accomplished with a relatively high degree of accuracy and with economy of water by detailed determinations of the field capacity and wilting range of the soil, and by measuring at frequent intervals the growth rate of the fruit and the moisture content of the soil. Less accurate, but relatively satisfactory control may be carried out by means of less detailed soil sampling and some indirect means of estimating the "wilting point" of the soil, or by fruit growth measurements on a small proportion of the trees in an orchard.

Because these methods are expensive or laborious, or as is true of the fruit-growth method, not applicable if the trees are not carrying immature fruit, most growers do not use any of them. The majority of growers whose orchards are irrigated on a schedule fixed by the water company estimate the amount of water required from the appearance and feel of the soil, the appearance of the trees, and from an estimate of the effect of weather conditions, all in relation to past experience with that particular orchard. If water is obtained on demand, both the time of irrigation and amount of water required to wet the soil to field capacity are estimated. Considering the number of variables which must be integrated, the judgment of many experienced growers is remarkably good; in fact, moisture control based upon the experienced grower's judgment is sometimes superior to that based upon too meager soil sampling. It seems likely, however, that the grower's judgment as to when and how much water should be applied might be appreciably improved if he had available a single valued measure of the effect of solar radiation, air temperature, relative humidity, and wind on transpiration. Such a measure is provided by the rate of evaporation from a free water surface in a shallow black pan evaporimeter. Briggs and Shantz (1), who devised the shallow black pan evaporimeter, in several tests with different kinds of plants found correlation coefficients of .89 to .95 between the transpiration rate and evaporation rate from this pan.

The agreement between transpiration rate and evaporation rate from the shallow black pan was better than that from any of the several types of atmometers used, or from the deep pan evaporimeter.

Recently Mortensen and Hawthorn (3) used the accumulated evaporation from a 10-foot pan, and Wilson (6), and Comin and Wilson (2) used the accumulated evaporation from an atmometer as a means of establishing arbitrary intervals between irrigations on field plots of vegetables. Taylor (4) found the average monthly soil moisture extraction rate of mature citrus trees to be closely related to the average evaporation rate from the recording shallow black pan evaporimeter described by Taylor and Nickle (5).

The present investigation was carried out to determine whether evaporation from the shallow black pan evaporimeter provides a sufficiently reliable means of estimating soil moisture extraction by citrus to be useful in managing irrigation plots and in controlling moisture under usual orchard conditions by the grower or by commercial laboratories.

The recording evaporimeter and a Mariotte reservoir evaporimeter have been used. Both have pans 25.23 inches in diameter and 1 inch deep, and the rates of evaporation from the two are practically identical. The recording evaporimeter is in some respects very convenient, but is relatively expensive, and it is sometimes difficult, as a result of wind action or rain, to read the values from the chart. The line drawing in Fig. 1 shows the construction of the Mariotte reservoir evapo

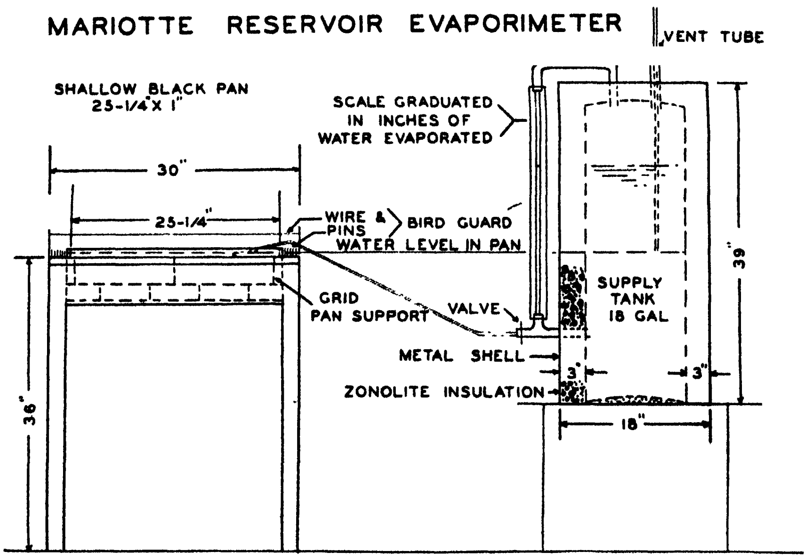

FIG. 1. Mariotte reservoir evaporimeter showing arrangement of insulated supply tank, vent tube, pan supply tube, gauge tube and scale, and pan support.

rimeter. The supply tank is enclosed in a water-tight galvanized iron shell, with 3 inches of Zonolite insulation between the shell and tank. The pan rests upon a latticed wood support, designed to store very little heat. Protection from birds is secured by a pan collar which supports a screen of fine wires criss-crossed at 4-inch intervals, and a ring of 3-inch brass pins soldered to the surface of the collar. Evaporation from the pan may be read directly in inches to the nearest .01 inch on the gauge scale.

The routine records of field capacity, wilting range, soil moisture percentages, irrigation water applied, and fruit growth on 18 irrigation plots of citrus distributed over three soil types provided ample data with which to test the reliability of soil moisture extraction estimates made from evaporation data.

Evaporation coefficients for each plot were calculated from the soil moisture extraction records and the evaporation records of 1939. The evaporation coefficient is the ratio of total soil moisture extraction in acre inches per acre for a given time interval to the accumulated evaporation in inches for the same time. The evaporation coefficients calculated from extraction and evaporation in 1939 were used in estimating the extraction in 1940. It became apparent during the season of 1940 that on plots which were allowed to become relatively dry different coefficients for early and late season must be used, because some of the soil in the sampling zone is not rewetted at each irrigation, and consequently the extraction total in relation to evaporation is reduced. Loss of leaf surface or lack of new growth late in the season may also affect the relative extraction rate in these plots.

The methods of calculating the evaporation coefficient and the conversion of soil moisture extraction in percentage of moisture to equivalent acre inches per acre may be illustrated from the data in Table I,

TABLE I—DETERMINATION OF COEFFICIENT FROM SEASONAL SUMMARY OF EVAPORATION AND SOIL MOISTURE EXTRACTION (ORCHARD D, SEASON 1939)

Soil Moisture Changes				Difference Moisture Content (Per Cent)	Evaporation on Irrigation Dates	
From	Moisture Content (Per Cent)	To	Moisture Content (Per Cent)		Date	Inches
Jun 6	26.5	Jun 25	21 5	5.0	Jun 25	0.30
Jun 26	29.3	Jul 26	24.4	4.9	Jul 26	0.42
Jul 27	29.0	Aug 18	25.0	4.0	Aug 18	0.33
Aug 19	31.5	Sep 3	28.3	3.2	Sep 3	0.26
Sep 4	31.0	Sep 25	27.5	3.5		
Total				20.6		1.31

Total Evaporation = 67.11 (Sep 25) − 29.80 (Jun 6) = 37.31 inches

$$\text{Extraction } D = \frac{Pvd}{100} = \frac{20.6 \times 1.10 \times 48}{100} = 10.95 \text{ acre inches per acre}$$

Evaporation 37.31 − 1.31 = 36.00

$$\frac{10.95}{36.00} = 0.304$$

D = the depth of water extracted in acre inches per acre
P = the per cent change in moisture content
v = the apparent specific gravity
d = the depth of the soil sampled

in which are tabulated the decreases in soil moisture content during each interval between irrigations in orchard D. The moisture extracted from the soil during the irrigation season was computed by means of the formula $D = \frac{Pvd}{100}$, where D is the depth of water extracted in acre inches per acre, P the per cent change of soil moisture for the particular time interval, v the apparent specific gravity of the soil mass sampled, and d the depth in inches of soil sampled. The sum of the differences, or changes, for the season was 20.6 per cent and the computed soil moisture extraction was 10.95 acre inches per acre. The evaporation during the same time interval was 37.31 inches. From this amount was subtracted 1.31 inches, the evaporation from the pan

during the time irrigation water was applied. This results in an adjusted evaporation of 36.0 inches.

The evaporation coefficient for orchard D, calculated by dividing the seasonal soil moisture extraction of 10.95 inches by the adjusted seasonal evaporation of 36 inches, was 0.304.

In 1940 an evaporation coefficient of 0.3 was used for orchard D early in the season, but from August 1 to October a coefficient of .25 was used. In this orchard, which was irrigated by sprinklers, the extraction was calculated for the entire soil area to a depth of 4 feet, but the soil was not wetted uniformly to that depth by the sprinklers so that by mid-summer the unirrigated soil was relatively dry and the total extraction was consequently reduced slightly.

The method of calculating the predicted soil moisture percentages and a comparison of the predicted and observed values are shown in Table II.

In making a prediction of the value of the soil moisture for any date it was necessary to have the accumulated evaporation for the interval since the last irrigation date. This amount in inches of water was multiplied by the coefficient 0.3 to obtain soil moisture extraction for the same interval in terms of acre inches per acre, and by the formula $D = \frac{Pvd}{100}$ the equivalent moisture change in per cent was determined for the acre inches of soil moisture extracted. This moisture change was subtracted from the value of the soil moisture at the

TABLE II—Water Application, Evaporation, Calculated and Observed Soil Moisture Values, Orchard D, on Yolo Clay Loam Soil (Season April 26 to October 25, 1940)

Date	Moisture Additions			Evaporation Record		Soil Moisture Changes			Observed Soil Moisture	
	Rain (Inches)	Irrigations		Accumulated Evaportion (Inches)	Evaportion for Period (Inches)	Extraction for Period (Inches)	Soil Moisture (Per Cent)	Soil Moisture Prediction (Per Cent)	(Per Cent)	Deviation (Per Cent)
		App. (Inches)	Net (Inches)							
Columns 1	2	3	4	5	6	7	8	9	10	11
Apr 26..	1.08	—	—	16.33	—	—	—	31.0	31.0	—
Jun 5...	—	—	—	27.46	11.13	3.34	-6.2	24.8	24.0	0.8
Jun 6...	—	2.84	2.27	27.69	—	—	4.3	29.1	—	—
Jun 10..	—	—	—	28.56	0.87	0.26	-0.5	28.6	28.7	0.1
Jul 2. ..	—	—	—	35.21	6.65	2.00	-3.8	24.8	25.4	0.6
Jul 4....	—	—	—	35.90	0.69	0.21	-0.3	24.5	—	—
Jul 5 ...	—	3.10	2.48	36.30	—	—	4.7	29.2	—	—
Jul 8 ...	—	—	—	37.69	1.39	0.42	-0.8	28.4	28.5	0.1
Jul 25...	—	—	—	44.83	7.14	2.14	-4.0	24.4	24.9	0.5
Jul 26...	—	2.90	2.32	45.17	—	—	4.3	28.7	—	—
Aug 1...	—	—	—	46.92	1.75	0.44	-0.8	27.9	28.8	0.9
Aug 26..	—	—	—	55.27	8.35	2.09	-4.0	23.9	23.1	0.8
Aug 27..	—	3.01	2.40	55.57	—	—	4.5	28.4	—	—
Aug 30..	—	—	—	56.50	0.93	0.23	-0.4	28.0	28.5	0.5
Sep 25..	—	—	—	63.70	7.20	1.80	-3.4	24.6	24.3	0.3
Sep 26..	—	2.67	2.14	63.97	—	—	4.0	28.6	—	—
Sep 30..	—	—	—	65.12	1.15	0.29	-0.5	28.1	29.3	1.2
Oct 23..	—	—	—	70.71	5.59	1.40	-2.6	25.5	25.5	0

Coefficient—0.30 April to August
—0.25 August to October
Irrigation Efficiency 80 per cent

beginning of the irrigation interval. This is made clear by following through the calculations shown in Table II.

On April 26, the date of the last effective spring rain, the soil mass was brought up to its approximate field capacity of 31 per cent (column 9). The first irrigation came on June 6, when 2.84 acre inches per acre (column 3) of water was applied to the orchard by means of sprinklers set near the ground. The efficiency of applying water in such a manner was found to be about 80 per cent. The net amount of water retained by the soil was 2.27 inches (column 4).

The accumulated evaporation from April 26 to June 5 amounted to 11.13 inches (column 6). Using the coefficient of 0.3 the soil moisture extracted for the period was estimated to be 3.34 inches (column 7), and by calculation was equivalent to a soil moisture decrease of 6.2 per cent (column 8). After subtracting 6.2 from the field capacity of 31 per cent the predicted soil moisture value was 24.8 per cent (column 9). From the soil samples taken June 5, the day before irrigation, the average value for 4 feet of soil was 24 per cent (column 10) or a difference of 0.8 per cent moisture content (column 11). As a result of the irrigation the net sum of 2.27 (column 4) acre inches per acre raised the average moisture content 4.3 per cent (column 8) to 29.1 per cent (column 9).

This soil drains to ap-

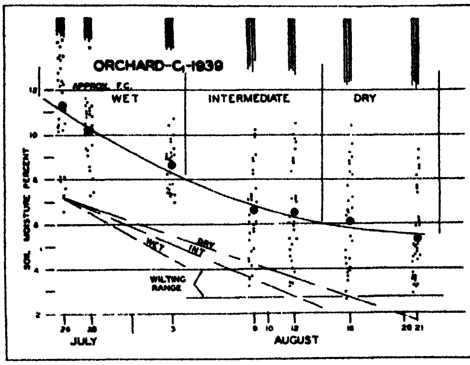

FIG. 2. Soil moisture content and extraction rates in a lemon orchard on Hanford fine sandy loam soil. Solid dots represent percentages of moisture in single samples; large circles represent the average percentages in the top 4 feet; and the broken lines represent rates of extraction under wet, intermediate and dry conditions.

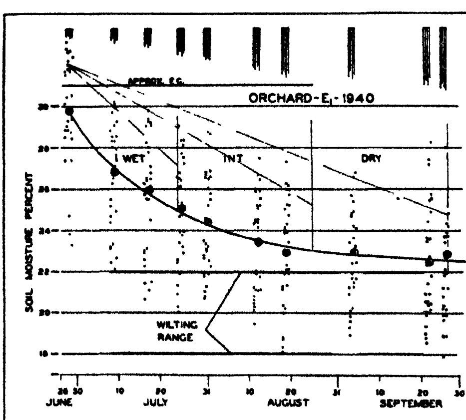

FIG. 3. Soil moisture content and extraction rates in a Valencia orange orchard on Yolo clay loam soil. Solid dots represent percentages of moisture in single samples; large circles represent the average percentages in the top 4 feet; and the broken lines represent rates of extraction under wet, intermediate and dry conditions.

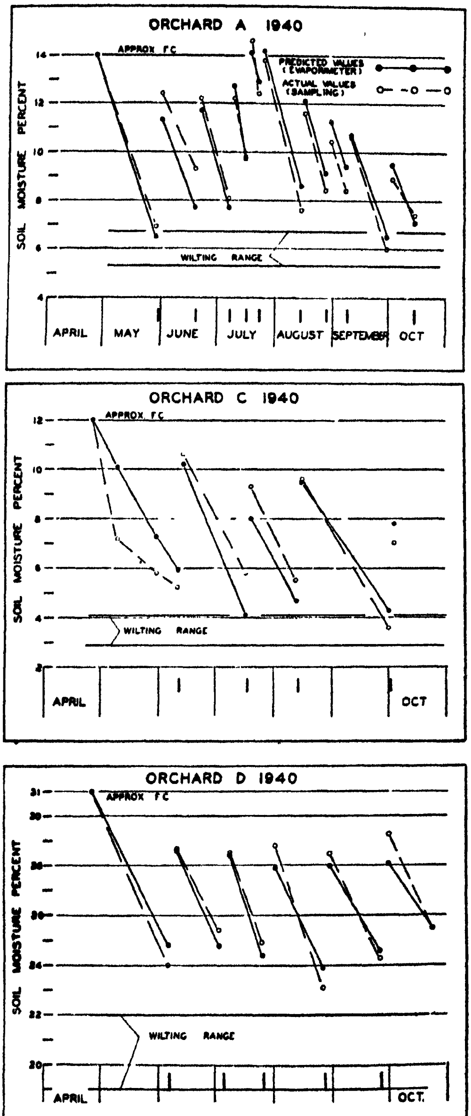

FIG. 4. Comparison of observed and predicted soil moisture percentages at the beginning and end of intervals between irrigations. Orchard A, Washington Navel oranges on Greenfield loam; Orchard C, lemons on Hanford fine sandy loam; Orchard D, Valencia oranges on Yolo clay loam.

proximate field capacity in about 3 or 4 days. Hence, soil samples were taken 4 days after the irrigation. By following the same procedure as above, the predicted value for June 10 was 28.6 per cent (column 9) and the actual value from sampling, 28.7 per cent (column 10), or a difference of 0.1 per cent (column 11) moisture content.

In the wetted zone root concentration varies greatly. Therefore, in soil zones of high root concentration, the moisture content of soil will eventually be reduced to values near or in the wilting range, while that of other parts may not be reduced far below field capacity. As the time after irrigation is increased, the proportion of soil with moisture content in the wilting range is increased. This finally results in a reduction in the total water extraction in the irrigated zone.

This effect is illustrated by the curves in Figs. 2 and 3. The average extraction rates for three soil moisture content ranges (wet, intermediate, and dry) are shown in relation to the moisture content of the wetted soil of one plot in orchard C (Fig. 2) and of one plot in orchard E (Fig. 3). It is, presumably, this changing rate of extraction in relation to proportion of soil in the wilt-

ing range allowed during each interval between irrigations which makes it necessary to use a lower evaporation coefficient for estimating soil moisture extraction for long than for short intervals between irrigations in a given orchard.

The relationship between the predicted soil moisture values and the observed values obtained for three different soils, light, medium, and heavy, during the 1940 season is shown in Fig. 4. The remarkably close agreement in most cases between the calculated and observed values illustrates the results which may be expected when the evaporation coefficient is obtained from detailed soil moisture records, and when the irrigation water is applied with unusual uniformity on orchards selected for uniformity of trees and soil. That such agreement will be obtained under practical orchard operation of large areas with less uniform trees and soil, is hardly likely. The data shown in Fig. 4, however, indicate that the idea of using evaporation as an index of soil moisture extraction by mature citrus trees is basically sound.

The relation between the accumulated evaporation for each interval between irrigations, and the soil moisture content, and the fruit volume gain are shown for three plots (wet, intermediate, and dry) of orchard D in Fig. 5. It may be noted that the greater the accumulated evaporation allowed before an irrigation, in general, the lower is the average soil moisture content and the lower is the rate of fruit volume gain.

The application of the results of the tests reported here to soil moisture control under practical orchard conditions presents some difficulties. Relatively few orchards have facilities for obtaining the soil moisture data essential for calculating the evaporation coefficient accurately and in most orchards the application of water is far from uniform. However, some orchards do have such facilities or commercial laboratories might be employed to determine the evaporation coefficient. It is quite possible that once the coefficient is worked out by extensive soil sampling the estimated soil moisture content may be found to be as reliable as the values found from the meager sampling usually practiced in commercial soil moisture control. The unreliability of a few scattered samples may be imagined from consideration of the variability shown in soil mois-

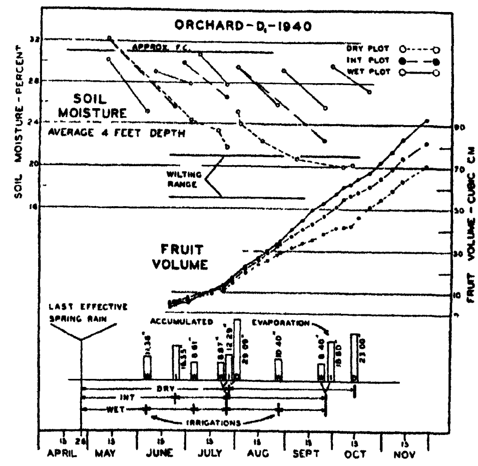

FIG. 5. Observed soil moisture content; volume of fruit; accumulated evaporation during each interval between irrigations; the time of irrigations on wet, intermediate, and dry plots. Orchard D, Valencia oranges on Yolo clay loam.

ture percentages in Fig. 3. Even without sampling it should be possible by trial and error to arrive at a fairly reliable evaporation coefficient by determining the relation between the accumulated evaporation and the fruit growth rate, or by judging from the appearance of the trees and soil the approximate accumulation of evaporation allowable before irrigating, and by making adjustments in the amount of evaporation allowed as experience indicates that the water was applied too late or sooner than was necessary.

At present, limited trial of the use of evaporation as an index of soil moisture extraction is being made by a few growers but is not yet recommended for general use by growers.

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Correction of Manganese-Deficiency Symptoms of Walnut Trees

By O. L. Braucher and R. W. Southwick, *University of California, Riverside, Calif.*

RESPONSES of English walnut trees to injections of manganese salts were reported by J. P. Bennett in 1932. This work was done in the Santa Clara Valley. In 1938, W. H. Chandler and others reported similar responses on trees in Santa Barbara and San Luis Obispo counties.

In 1935, leaf samples were taken from both severely affected and normal trees. These samples were analyzed by A. P. Vanselow, and, on the basis of quantitative spectrographic analyses, he reported the manganese content of dry matter in parts per million as 80.0 in normal leaves and 6.5 in badly mottled leaves.

While manganese-deficiency symptoms have been reported in many other crops for several years, the recognition of these symptoms in walnuts is relatively new. The probable scope of this problem with relation to walnuts cannot be outlined at the present time, since, like any relatively new deficiency disease, the recognition of all of its manifestations under field conditions will require additional time. The economic aspect of this problem is also unknown, except in a few areas, limited in size, where death of the tree occurs in a relatively few years unless corrective measures are undertaken.

Recognition of Symptoms

Symptoms of manganese deficiency are somewhat similar to those of zinc deficiency in the milder or more moderate stages. The leaves become mottled between the veins, the area adjacent to the veins remaining green. However, as the season advances this mottled pattern becomes more pronounced and the mottled areas which were formerly lighter colored than the areas adjacent to the veins takes on a bronze color. Typical "little leaves", characteristic of severe zinc deficiency, do not occur.

In the moderately severe and severe cases of manganese deficiency, burning of the leaves may take place in the area between the veins. In many respects the pattern of these burned areas may be somewhat similar to boron-excess burn. But the burned areas seem to be sharply defined and angular in shape, whereas the boron-excess symptoms may at times be rounded or blotchy in pattern.

In the case of manganese deficiency, mottling may be apparent as early as May 10 and, if severe, a high percentage of leaves may be burned and actual leaf drop may occur by June 1.

Fig. 1 shows a normal walnut leaf and leaves with varying degrees of manganese deficiency symptoms.

Methods of Treatment

Working in Ventura County, the writers have approached the correction of manganese-deficiency symptoms by the following methods:

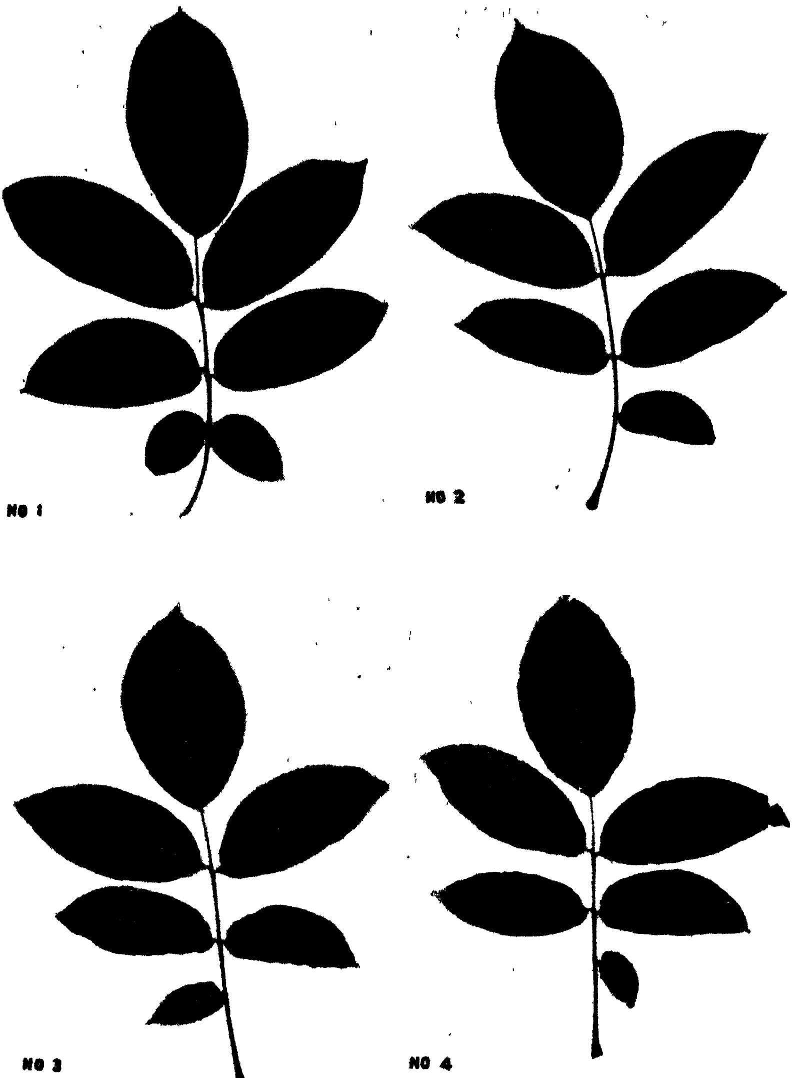

FIG. 1. Manganese deficiency symptoms: 1, normal leaf; 2, slightly affected leaf; 3, moderately affected leaf; and 4, severely affected leaf.

(a) injection of dry manganese salts; (b) liquid injection of manganese salts under high pressures; (c) spraying manganese salts onto the tree; and (d) soil treatments consisting of manganese sulfate and sulfur, as well as sulfur alone.

Injection has been highly successful as a laboratory method to demonstrate the effectiveness of manganous sulfate in correcting the symptoms or curing the tree of this deficiency disease. Dry salt injec-

tions made during the summer or winter months produce an outstanding response the following season. Early summer injections may or may not show clear-cut responses the same season.

Severe bark injury does not usually occur as a result of the dry salt injections. However, some wood injury occurs. What the ultimate effect of this wood injury will be cannot be predicted. But repeated injections could possibly weaken the main framework of the tree.

Dry salt injections are made by boring holes into the wood. The holes are ⅜ inch in diameter, and are 2 to 4 inches in depth depending upon the size of limb or tree trunk. The holes are staggered and never closer than 4 inches from one another. Amounts of manganous sulfate per hole have been varied from 1 gram to as much as 10 grams per hole. In limbs 4 to 6 inches in diameter it has been observed that small amounts of manganous sulfate (1 gram per hole) and four holes per limb are extremely slow to produce a response and, if a response is noted, it is quite poor. Five grams of material per hole and four holes on limbs 4 to 6 inches in diameter give good responses. Amounts as great as 10 grams per hole have been used with no apparent increase in wood injury over the 5-gram application.

Fig. 2 illustrates an injected limb on a tree that exhibited severe manganese deficiency symptoms. This picture was made the latter part of September. This limb, like other similarly treated limbs, held its leaves until late in October, which is normal, whereas the remainder of the tree had lost most of its leaves by August 1.

Liquid injections under pressures of 100 to 125 pounds have been tried. Here the manganous sulfate is injected into the tree trunk. Amounts of this salt up to 75 grams per tree have not produced much leaf burn.

Fig. 2. Recovery of limb (right side of tree) resulting from injection of manganous sulfate.

Spraying manganese salts onto the tree has been given preliminary trials and the following results have been observed: Manganese sulfate in amounts up to 25 pounds per 100 gallons of water applied in the dormant season has produced no response; applied on small foliage in the spring (March 15 to April 15) very little or no response. The spray strength was varied from 5 pounds to 20 pounds per 100 gallons of water. Slight leaf burn occurred where 20 pounds per 100 gallons was used but 5 and 10 pounds per 100 gallons caused no injury.

There are, however, good responses when sprays are applied during late May and June. The concentration of manganese sulfate has been varied from as low as 5 pounds per 100 gallons to as high as 25 pounds per 100 gallons. Leaf burn has occurred when 20 and 25 pounds of the material per 100 gallons were used. In some instances the trees lost nearly 50 per cent of the leaves when these higher concentrations were used. Five, 10, and 15 pounds of manganese sulfate per 100 gallons have not caused leaf burn when applied during this period (May 15 to June 30).

Mid-summer sprays and late summer sprays have shown very slight responses. Here again concentrations have been from 5 to 25 pounds per 100 gallons. Injury to foliage has occurred only with the 20- and 25-pound concentrations.

The use of safeners such as hydrated lime and soda ash has been tested in a limited manner. At present the indications are not conclusive as to the need for these materials, but since burn does not occur without safeners at the lower concentrations, their use is optional.

Tagging of leaves has been done wherever sprays have been applied during the growing season.

Severely mottled leaves, when sprayed during the May 15-June 30 period, cleared up and remained normal the rest of the season. Mottled and burned leaves respond more slowly if the burned areas are only a small portion of the leaf. Leaves which are severely burned before the spray is applied usually fall before there is any recovery in the green or live part.

The Climacteric Rise in Respiration Rate of the Fuerte Avocado Fruit

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THE relationship between carbon dioxide evolution and fruit ripening has been investigated widely for some of the deciduous fruits. With the apple and pear, in particular, it has been shown (4, 5) that changes in certain manifestations of maturity are accompanied by a greatly accelerated rate of respiration. Similar observations were made for the banana (2). This rapid increase in carbon dioxide production is referred to by workers in this field as the "climacteric" rise in respiration. Not all fruits appear to exhibit this respiratory trend, however. In the lemon and orange, which have relatively low respiring power, no climacteric has thus far been observed (1).

Very meager information exists concerning the course of respiration of the avocado fruit after harvesting (6, 7). In one case it was obtained by placing fruits of the Fuerte variety into an air tight container, and subjecting them therefore to an environment the gaseous composition of which was continuously changing. The accumulation of carbon dioxide evolved by the fruit in a sealed container, associated with decreasing oxygen content was doubtless one of the causes for the declining respiration rate observed (6). The striking sensitivity of the avocado fruit to oxygen deficiency will be shown in some of the experiments here reported. The principal emphasis in these preliminary studies, however, was placed on the respiratory behavior of the avocado in relation to the ripening and softening processes.

The Climacteric Under Air

The Course of Respiration at 15 Degrees C (Experiment 1):—The procedure for this experiment, and also for those which follow, was essentially similar to that employed in studies on citrus fruits previously reported (1). The avocados were picked February 17, 1941, from 5-year-old trees in the orchard of the Division of Subtropical Horticulture at the University of California, Los Angeles. The next day each respiration jar, containing 30 fruits, was placed in an air conditioned room maintained at 15 degrees ± 0.5 degrees C. The fruit was horticulturally mature but firm. A continuous stream of air at 350 cubic centimeters/minute was used during the carbon dioxide determinations as well as between readings. While measuring respiration the air stream was freed of carbon dioxide by means of ascarite. The results are shown in Table I.

In this table the values for each jar were computed from three or more consecutive hourly or semi-hourly determinations. The largest increase in respiration rate above the initial reading varied from about 80 to 100 per cent for the three jars. However, when the maxima are considered by themselves without reference to the initial reading on February 20, it will be seen that they differ by approximately 1 to 4 per cent from the average. The rate of the climacteric rise appears to be somewhat more rapid for jar No. 6 than for the other two.

TABLE I—RESPIRATION OF FUERTE AVOCADOS SUBJECTED TO AIR AT 15 DEGREES C (IN MILLIGRAMS CARBON DIOXIDE PER KG OF FRUIT PER HOUR)

Jar No.	February						
	20	22	24	25	26	27	28
6..........	67.2	67.4	109.0	112.9	126.6	113.5	103.3
7..........	63.2	—	65.6	80.6	109.3	122.5	127.2
8..........	67.6	51.0	58.7	89.5	111.0	120.4	119.2
Average.....	66.0	59.2	77.8	94.3	115.6	118.8	116.6
Jar No.	**March**						
	1	3	4	5	6	7	8
6..........	77.2	67.4	53.0	56.1	46.0	50.9	48.2
7..........	100.9	84.0	71.4	76.6	65.0	—	63.0
8..........	93.8	83.5	68.5	72.6	62.5	69.4	62.9
Average.....	90.6	78.3	64.3	68.4	57.8	60.2	58.0

It is of interest to compare the degree of softening of the fruit with its respiratory behavior. On February 25 all the avocados were firm. Three days later in jar No. 6 all were soft and in the edible stage while in No. 7 there were only two soft, and in No. 8 six soft fruits. On March 8 when the experiment was terminated two-thirds of the fruit in No. 6 had passed the edible stage, while in the two other containers less than one-third was classified as very soft. Darkening of the peel was observed at the same time in the three jars but was more pronounced in No. 6. Insufficient data are available to warrant conclusions at present as to the exact relationship between the climacteric and softening, but observations made in this and in other experiments suggest that the maximum in carbon dioxide output precedes softening by one to three days under the conditions employed here.

Effects of Low Temperature on Respiration (Experiment 2):—For the purpose of determining the effects of an initial exposure to low temperature on the subsequent respiration behavior, fruits from the same lot used in experiment 1 were placed at a temperature of 4 to 5 degrees C. In Fig. 1 the results are presented graphically and compared with the averages obtained from the previous experiment. Because of the close agreement between the three jars when exposed to the low temperature, averages only are reported for the period February 21 to March 10, both inclusive. At the end of this period all the fruit was found to be firm. At 4 p.m. on March 10, jar No. 9 was transferred to the ripening temperature of 15 degrees C. The next day the respiration rate rose immediately to a value higher than the initial rate for jars No. 6, 7, and 8, which had received no preliminary low temperature exposure. In 5 days the maximum carbon dioxide output was reached, and 3 days later the fruit started to soften and shortly thereafter reached the edible stage. Similarly, jar No. 10 was transferred to 15 degrees C on March 17 and jar No. 12 on March 26. The resultant responses were essentially similar to those of jar No. 9. The maximum rise in respiration for these three jars compares closely with that for jars No. 6, 7, and 8.

It is also of interest to evaluate the temperature coefficient, Q_{10}, for

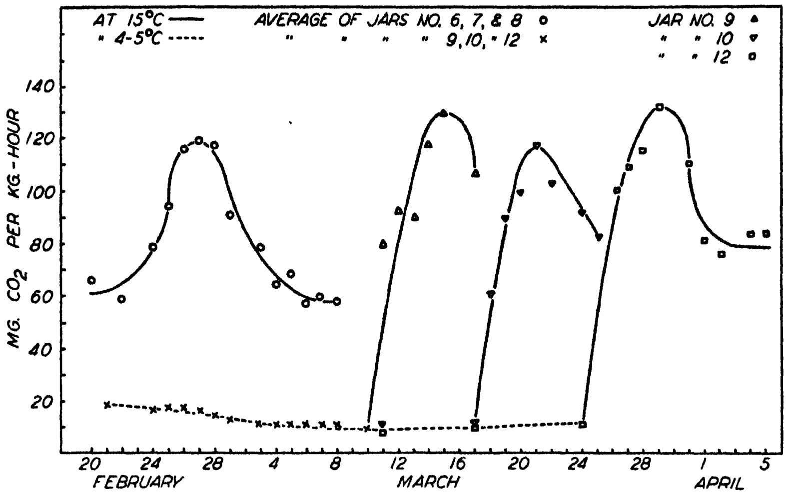

FIG. 1. Effect of temperature on the climacteric rise in respiration of Fuerte Avocado fruits.

the avocado. In the range of 5 to 15 degrees C it changes from approximately 3.5 in the pre-climacteric phase through 7.0 at maximum respiration to about 3.3 in the final post-climacteric stage. The magnitude of respiration is very much higher for the avocado than for citrus fruits. At 15 degrees C green lemons immediately after picking when their respiration rate is at a maximum respire one-sixth to one-eighth as actively as do avocados in their pre-climacteric stage. As a matter of fact, avocados produce at least as much carbon dioxide at 4 to 5 degrees C as do lemons at 15 degrees C.

THE CLIMACTERIC AS AFFECTED BY DIFFERENT GASEOUS ATMOSPHERES

Aerobic Versus Anaerobic Respiration at 15 Degrees C (Experiment 3):—As a preliminary to gas storage trials, it seemed desirable to ascertain the effects on respiration of the limiting conditions of a completely anaerobic atmosphere. For this experiment the fruit was picked all from one tree in the orchard March 12, 1941, and subjected to 15 degrees C the same day. Twenty fruits were placed in each jar, with two jars under a continuous stream of nitrogen and two under air. A rate of 100 cubic centimeters/minute was employed except during respiration determinations when the rate was increased to 350 cubic centimeters/minute. The nitrogen was freed of traces of oxygen by passing it over hot copper filings. The variations between individual jars in each treatment were small with the exception of the air jars during the climacteric period. Under aerobic conditions maximum carbon dioxide output for jar No. 6 was 153 and for No. 7, 138 milligrams per killogram-hour. This difference of approximately 10 per cent is greater than normally occurs, but excluding this instance the agreements between individual jars in each treatment were so close

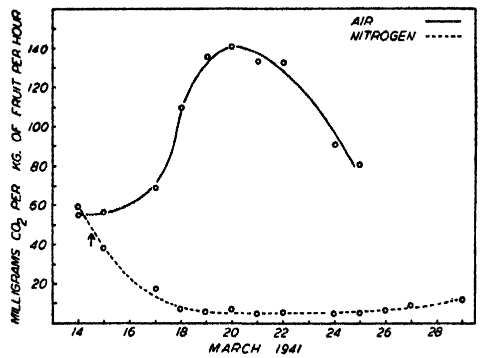

FIG. 2. Aerobic and anaerobic respiration of the Fuerte Avocado fruit (arrow indicates the start of exposure to nitrogen gas).

as to make it possible to present in Fig. 2 curves based on averages.

In this experiment the behavior of the fruit under air was similar to that in experiment 1 with the exception of a somewhat higher maximum. Here too softening followed the climacteric. On March 19 all fruit were firm, while on March 21 slight softening was noted though most of the fruits were still firm. The next day they were nearly all in the edible stage. This condition had developed 1 day after the maximum climacteric respiratory activity.

In striking contrast to the aerobic respiration, jars No. 1 and No. 5 under nitrogen showed a sharply declining carbon dioxide output until March 18 and a low level thereafter. At the height of the climacteric the ratio of aerobic to anaerobic carbon dioxide evolution was 8.2. This value is considerably higher than that obtained for other fruits in general. In citrus, for example, anaerobic carbon dioxide production has been found not to differ appreciably from aerobic respiration. Apparently the enzymatic system of the avocado is highly sensitive to the lack of oxygen.

It is further to be noted that the fruit in the anaerobic atmosphere retained its firmness until the end of the experiment. A putrid odor was detectable in the air leaving the nitrogen jars. The experiment was discontinued when the fruit was covered with micro-organisms, apparently fungi. The somewhat higher final respiration readings might have been due, therefore, to fungal invasion.

Aerobic Versus Anaerobic Respiration at Low Temperatures:— The effects of a nitrogen atmosphere were studied also at a storage temperature of 4 degrees C. The fruit for this study came from Escondido and was placed in storage February 15, 1941. In this experiment only six fruits per container were used. It was found that the uniformity of consecutive readings compared favorably with that obtained with larger samples. Initially all containers were placed under air for several days. On February 24, the differential treatment was started and respiration measurements were limited to two per day since the low carbon-dioxide losses made it necessary to carry the determinations over a 2-hour period. Table II presents the results of this experiment.

In all containers a slight initial decrease is to be noted. Under air a steady state was soon attained while under nitrogen the fall was continuous. Some of the daily variations may be ascribed to temperature

TABLE II—EFFECT OF AIR AND NITROGEN ON RESPIRATION OF AVOCADOS AT FOUR DEGREES C (IN MILLIGRAMS CARBON DIOXIDE PER KG OF FRUIT PER HOUR)

Jar	February								
	20	21	22	24	Differential Treatment	25	26	27	28
B	15.9	13.0	12.4	11.1	Air	16.8	12.6	11.9	15.9
C	17.2	11.3	11.1	8.7	Air	11.3	9.9	10.7	11.4
D	17.4	15.2	14.9	13.3	Nitrogen	18.0	11.8	8.8	9.9
E	20.3	17.1	16.6	14.4	Nitrogen	19.0	12.1	10.3	9.7

Jar	March						
	1	3	4	5	6	7	8
B	17.2	12.3	12.8	10.6	12.8	12.1	12.6
C	17.5	11.4	12.0	11.0	11.9	12.3	12.1
D	7.8	6.8	8.6	6.4	6.2	5.8	5.8
E	8.6	7.9	8.7	7.3	6.9	6.6	5.8

fluctuation in the chamber which could not be maintained as constant as the 15 degrees C room. Nevertheless, the data clearly show a depressing effect of nitrogen even at the lower temperature. This effect appears, however, to be reversible because upon change to air at the same temperature on March 10, an immediate recovery of the respiration rate took place. When jars D and E were subsequently transferred to air at 15 degrees C the characteristic climacteric rise in carbon dioxide output resulted. The maximum value in respiration was lower by 10 and 15 per cent, respectively, in these jars than in B and C which were continuously under air, but no material difference in the rate of softening was observed.

DISCUSSION OF RESULTS

The most obvious conclusion from these experiments seems to be that softening of the avocado fruit is associated with a climacteric rise in the rate of respiration. It is of interest therefore to compare the magnitude of this rise with that for other fruits which behave similarly. At a temperature of 20 degrees C Kidd and West (4) reported for the apple a maximum respiration of 25 milligrams CO_2 per kilogram hour. Magness and Ballard (5) working with pears at 15.5 degrees C found the respiration rate to attain a value of 50 to 60 milligrams CO_2 per kilogram hour, while Gane (2) has observed bananas at 15 degrees C to produce 60 to 70 milligrams CO_2 per kilogram-hour at the peak of the climacteric. The maximum carbon dioxide output by the Fuerte avocado of 120 to 150 milligrams per kilogram-hour is therefore much higher. When the percentage increase of the maximum over the initial respiration rates is considered, however, the avocado will be observed not to differ markedly from some of the other fruits referred to. The above mentioned workers have found this increase to be 100 to 200 per cent for the apple, 200 to 300 for the banana, and 300 to 400 per cent for the pear. In the avocado the rise in respiration at the peak of the climacteric over the initial rate is of the order of 100 to 200 per cent.

The reasons for this climacteric trend have not been established.

Enzymatic activation may provide an explanation for the rapid acceleration in respiration rate during the climacteric. The fall in carbon dioxide evolution in the post-climacteric stage may be the result of substrate shortage. If it is assumed that sugars are the immediate respiratory foodstuffs, computations based on the data in Fig. 1 indicate utilization of 1.1 per cent of substrate in 7 days. The avocado has been reported (3) to contain a maximum of about 2 per cent of total sugars on fresh weight basis. Sugars may, however, be supplied by the hydrolysis of other compounds present in the flesh. Only a complete chemical analysis in conjunction with physiological studies seems likely to throw light on these questions.

Conclusions

The respiratory activity of fruits of the Fuerte avocado variety at 15 degrees C is characterized by a rapid acceleration in carbon dioxide evolution followed by a pronounced decrease. At the peak of the activity 120 to 150 milligrams of carbon dioxide are produced by 1 kilogram of fruit per hour. This quantity is equivalent to an increase of 100 to 200 per cent over the initial rate. The climacteric rise has not been found to occur at 4 to 5 degrees C for a period of 5 weeks. The maximum in respiration precedes the onset of softening by 1 to 3 days.

The anaerobic respiration rate has been shown to be much lower than the aerobic rate with no climacteric rise and no softening of the fruit observed.

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The Brunswick (Magnolia) Fig

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THE Brunswick fig is a good example of a fruit variety which has been grown under many different names, one of which is apparently Magnolia. The following is a historical and descriptive account of Brunswick and of Magnolia submitted in an endeavor to show that the two are identical.

HISTORY AND DESCRIPTION OF BRUNSWICK

As early as 1768, Philip Miller (11), described the Madonna fig, commonly called Brunswick or Hanover, as a long pyramidal fruit of a large size, with brown skin and leaves much more divided than leaves of most figs. Other early descriptions of Brunswick are given by Hanbury (7), 1770; by Brookshaw (2), 1812;[1] by George Lindley (9), 1831; by John Lindley (10), 1841;[1] and by Gallesio (5), 1820.[1]

Robert Hogg (8) describes Brunswick and gives the following synonyms: Bayswater, Black Naples, Brown Hamburgh, Clementine, Hanover, Madonna, Large White Turkey, Red. He states that the figs (first crop) are very large and pyriform, oblique at the apex; skin greenish-yellow in the shade, pale brown on the exposed side; flesh opaline, rich, and of excellent quality. All the descriptions mentioned above refer only to the breba or first crop, the only one which ordinarily matures out of doors in England.

John Rogers (14) states that this variety was introduced under the name "Madonna" in Miller's day and renamed Brunswick in honor of the accession of George I.

Various writers give credit to Dr. Gustav Eisen for the statement that the Brunswick is an Italian fig transported to Brunswick (England,) whence the name. Eisen (4) describes Brunswick figs of both crops, stating that second-crop figs are medium or below in size, otherwise not much different from the brebas. He adds that the "tree is quite small with straggling branches, deeply cut leaves which, on account of their small size, as well as number, give little shade".

THE BRUNSWICK FIG IN CALIFORNIA

In California, as elsewhere, Brunswick is often confused with other varieties, some commission merchants in Los Angeles erroneously giving the name Brunswick to fresh Brown Turkey figs. According to Eisen (4), Brunswick was the most common "white" fig in California until the introduction of the Adriatic, about 1850.

Brunswick trees in California are not so vigorous in growth as Mission and Kadota. At Riverside, for example, 12-year-old Brunswick trees are less than one-fourth the size of nearby Kadota trees. Dooryard trees, however, which are frequently watered, grow vigorously and fruit prolifically. A few years ago some small commercial plantings were found near Elk Grove, Sacramento County. Neither

[1]Illustration of breba or first-crop figs in color.

in vigor of growth nor in production per acre did Brunswick compare favorably with Kadota. At Davis, W. H. Chandler (3) found that Brunswick trees were less than 25 per cent as vigorous as Kadota in the same soil and cultural conditions. Furthermore, a large percentage of Brunswick fruit buds failed to mature; buds were forming and dropping prematurely all summer.

Brunswick brebas, maturing in late June at Riverside, are very similar in size, shape, and color to the descriptions of this variety found in English publications. Main-crop figs maturing in August are medium, oblique-turbinate, mostly without neck; stalk often prominently swollen or enlarged; eye rather large, open; color bronze; pulp practically seedless, amber with a tinge of strawberry. Leaves, especially on sucker wood, are narrowly lobed.

Figs Mistakenly Called Brunswick

Price (12) and Van Velzer (16) in Texas and Eisen (4) in California all refer to the fact that other figs are commonly designated as Brunswick. Starnes and Monroe (15) pointed out the desirability of determining correctly the identity of the Brunswick, two different figs having been exhibited under this name at the Jamestown Exposition in 1907.

Brunswick from Glen St. Mary Nurseries in Florida and from Angleton, Texas, have proven to be identical with Brown Turkey in California. Ten named varieties of figs received for trial from the Old World through the United States Department of Agriculture have all proven to be identical with the Brunswick.

History and Description of Magnolia

Probably the first publication of the variety name "Magnolia" was by Thomas Affleck (1), 1852, when he listed Jaune as "a large brown fig from France; the 'Magnolia Fig' ". H. R. Fulton and H. P. Gould, United States Department of Agriculture, surmise that Affleck received the Magnolia fig from Texas about 1848; that by 1852 he had decided it was the same as Jaune previously imported from France; and that the name Magnolia, being in quotation marks, is a synonym, since nowhere else in his calendar does Affleck so designate a varietal name.

Price and White (12) quote Gilbert Onderdonk as follows: "About sixty years ago a man came through the coast country selling magnolia trees. It developed that no one got magnolia trees but everyone had an excellent fig, and hence the variety of figs called Magnolia originated." As grown at the Texas Station, this variety proved to be identical with Brunswick, Dr. Hogg's Clare, and Barnisotte, all having the same characteristics of lop-sided shape of fruit, deeply cut foliage, and vigorous growth.

H. P. Gould, United States Department of Agriculture, visited Gilbert Onderdonk at Nursery, Texas, August 1, 1911, and learned that the so-called magnolia trees brought into the Gulf Coast section and sold at one dollar apiece, came on a ship which cleared from Tampico, Mexico. Onderdonk found the same variety in 1898, 150

miles from Tampico, about San Bartolo, Las Palmas, Cacota, and Cerritos.

Van Velzer (16) states that Brunswick has many pet names, among which are Magnolia, Hanover, and Madonna. He adds: "Those who still contend that the Magnolia is a new variety, distinct from the Brunswick, can discover their error by studying the leaves, bark, wood, and fruit, which have characteristics and habits that distinguish it from all others. Some nurserymen profit from this misconception by buying cuttings of Brunswick trees at a much lower price than is asked for Magnolia wood, and selling them afterward as the same stock."

The Magnolia fig is widely distributed throughout the southern and eastern states. Starnes and Monroe (15) describe the fruit as large to very large, axes practically equal; shape pyriform; neck very obtuse or wanting; stalk very short and thick; eye very large, open; skin thick, tough, greenish amber, overspread with brown; pulp pinkish amber; of good quality at first but "soured frightfully with wet weather and was consequently of no practical value". Gould (6) states that "Magnolia does not appear to be well adapted to regions east of the Mississippi River, various reports indicating that the tree makes a rather weak growth and that the fruit cracks badly".

Magnolia appears to be a variety of rather recent introduction since it is not found on such historic grounds as Wakefield, Stratford Hall, or Jamestown, Virginia, where other figs, notably Eastern Brown Turkey, are growing. In Northampton and Accomac counties, Virginia, Magnolia fig trees are common and are locally known under the name "Silver Leaf", though the reason for the name is not clear. At Cheriton and Onley, Virginia, growers do not favor Magnolia because of the tendency of the fruit to split. At Crisfield, Maryland, however, it is being planted commercially in a small way. Magnolia fig trees grow and produce an abundance of fruit on the south side of buildings in Washington, D. C.

The Magnolia fig is pre-eminently successful in the vicinity of Houston, Texas, where the mean annual rainfall is 40 inches and the mean relative atmospheric humidity is 80 per cent. There, if given proper care, the trees thrive and produce bountifully. Figs set and mature, often two figs to each leaf, and apparently there is little trouble from dropping of immature fruit. F. T. Ramsey (13) says that in some sections of Texas, Magnolia is called "Neverfail".

Conclusions

A comparison of the descriptions of Magnolia and Brunswick discloses such similarity of foliage, habit of growth, shape, size, and color of fruit, that there is ample justification for my opinion that these varieties are identical. English descriptions of Brunswick are mostly of the breba crop. In the United States, descriptions of this crop are almost entirely lacking since most trees in this country produce few brebas. However, Eisen's description of Brunswick brebas coincides very closely with descriptions made in England. Brebas maturing on trees at Riverside, California, also correspond to descriptions and illustrations given in English publications.

As for the second crop, my long and careful study of the Brunswick in California, in Texas, in the Eastern States, and even in China, leaves a clear picture of its characteristics and of its identity.

Magnolia has been brought from Texas into California many times by nurserymen, by growers, and by our State Agricultural Experiment Station. In every case it has proven to be identical with the true Brunswick which I obtained direct from England through the United States Department of Agriculture as Plant Introduction No. 93276. There is no doubt in my mind that Price and White, Van Velzer, and Eisen are correct in their belief that Brunswick and Magnolia are one and the same fig. It seems most probable that the names became confused because cuttings of Brunswick were grown in Texas under the name Magnolia and later were introduced into other states under the same name.

It is my hope that this article may give some idea of the ease with which incorrect names or synonyms may become attached to a variety. Especially, may it help to clarify the confusion that has long existed regarding the nomenclature of the fig variety, Brunswick.

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The Present Status of Chestnut Growing in the United States

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CHESTNUT growing in the United States is apparently at the threshold of a period of important development for the second time in history. Once before, for a period of almost 50 years, which began at about the time of the Civil War, there was widespread interest in planting chestnuts throughout much of the country, and in certain localities of eastern Pennsylvania, New Jersey and northern Maryland extensive areas of native chestnut coppice growth were grafted over with scions of select varieties, mainly European. In orchard plantings European and Japanese varieties were used to about equal extent.

All European varieties practically disappeared from the East during the early decades of the present century, along with the native chestnut, because of blight. Several European varieties are still being successfully grown on the West Coast. Japanese varieties usually withstand blight well and trees of this group are fairly common in many parts of the country; but, with few exceptions, the older varieties produced nuts of low palatability.

Present interest in chestnut planting, throughout the East and to a considerable extent on the Pacific Coast, is largely based upon recognized and potential varieties of two Asiatic species, the Chinese chestnut, *Castanea mollissima*, and the Japanese chestnut, *C. crenata*. Varietal selections are generally resistant to blight, fairly hardy, and under favorable conditions, commercially fruitful. The nuts are large enough to be readily acceptable to the trade, attractive to the eye and otherwise pleasing to the average consumer. The best of these "clean" well, that is, the kernels become automatically separated from the pellicles, their immediate coverings, as they are being removed from the shell.

Practically speaking, the Chinese chestnut was introduced into this country during the early part of this century by the United States Department of Agriculture. It is now known here chiefly as a seedling tree with all of the inherent variations common to ungrafted stock. These variations involve the character and symmetry of tree growth, and its hardiness, fruitfulness and resistance to blight, as well as the size and general character of the nuts. Nearly a dozen varieties have been recognized and propagated to some extent. About half of these are now available from commercial sources as grafted trees.

The Japanese chestnut was introduced during the sixties of the last century, mainly by private individuals. Many varieties have been developed but the tendency has been to stress size and appearance of nut rather than to develop quality. In consequence of this, few of the older varieties are in favor with experienced consumers. Several varieties, however, have recently come to light and are now being propagated by nurserymen, which compare favorably with the best varieties from either China or Europe.

Introduction of Oriental chestnuts by the United States Department of Agriculture has practically ceased, as there is little reason to suspect

that better chestnuts than those already here could be had from any source. Attention therefore, is being directed to the improvement of the varietal situation by selection and hybridization with material now in hand. The greater progress to date has been by the former method, but, as is the case with other plants now being improved, it is believed that much greater strides will be made by hybridization. As shown by Crane and associates (1) chestnut breeding by hybridization was begun during the early nineties by Endicott of Illinois and Van Fleet of New Jersey, working independently and unknown to each other. However, with the exception of Boone, a *Castanea crenata* x *dentata* hybrid, developed by Endicott, all varieties developed by these men, though promising at the time and of certain genetic value, soon became commercially obsolete for one reason or another, mainly because of susceptibility to blight.

Economic and cultural experience to date has netted certain results which should serve as valuable guideposts to future chestnut planters. A number of these are here discussed under separate headings.

The Market Situation

In spite of certain prejudice against chestnuts of all kinds because of occasional unhappy experiences with poor quality Japanese varieties, the consuming public readily accepts good chestnuts with little persuasion and at fair prices. Competition is usually keen in the East with chestnuts normally imported from southern Europe after about November first, and on the West Coast about a month later with chestnuts from the Orient. A yearly average of 16,777,200 pounds of chestnuts from all sources was imported during the 5-year period ending June 30, 1940.

Chestnut trees of the superior new varieties now being planted are unlikely to produce quantities of nuts sufficient to affect the general market for some years to come. So far as known, all that have yet been grown have been used either for seed and sample purposes, or consumed locally. The ripening period begins in late August in Georgia and about a month later in Maryland. The principal marketing period will probably be during October and such portion of November as may be ahead of the first imports. Upon a quality basis, the best home-grown chestnuts should be able to compete successfully with any which may be imported.

Chestnuts tend to deteriorate rapidly regardless of how they are handled. The period during which they may be marketed and consumed is relatively short. A week or 10 days is about as long as they may be held with safety on a market stand without the use of cold storage. A newly discovered and as yet unexplained disease, which causes the nuts to decay while ripening, is now resulting in considerable damage in chestnut plantings at low altitudes in the region from South Carolina to Louisiana.

Geographic Zones

Present indications are that the best zones for chestnuts coincide closely with those for the peach, although it is probable that chestnuts

may be grown both farther north and farther south than can the peach. Certain seedlings and varieties are apparently well suited to culture near Albany, Georgia and other southern points. Fair success is being reported from near Boston, Massachusetts and in Central New York. The nuts grow distinctly larger in the South than in the North.

Climatic Requirements

Chestnuts are adapted to a wide range of climatic conditions. They do well in the humid regions of the East and in the dry interior valleys of northern California. All chestnuts however, require considerable moisture in the soil and when rainfall is deficient, this must be supplied by artificial means. Young trees are notably sensitive to dry periods and perish quickly during drouths of spring or summer. Furthermore, without protection, the trunks are seriously subject to sunscald on the south side during hot sunny days. To overcome this, it is often necessary to erect boards or lath in such position as to protect the trunks during the heat of the day.

At the latitude of Washington, D. C., the chestnut flowering season occurs during June and July. For this reason, there is little danger of frost injury to the flowers at that time. However, serious injury and even death to the trees often occurs a month or two earlier while the buds are bursting into leaf, as the trees are especially sensitive at that time.

Cultural Requirements

Soil:—Suitability of soil is commonly, yet erroneously regarded as being less important with chestnuts than with most other nuts. Good soil is actually vitally important in the production of full crops of first-grade nuts. The importance of this can hardly be over-emphasized.

Planting Seasons:—Chestnuts are like most orchard species in that, in the southern part of the country and on the Pacific Coast, results are usually better with fall than with spring planting. However, spring planting is much safer in parts of the country where winters are especially trying.

Training and Pruning:—It is the experience at Beltsville, Maryland, that young trees make better growth if cut back to within a foot or 18 inches of the ground at the time of transplanting. Trees so cut make more rapid growth and are less subject to sunscald. Limb-cutting may be quite necessary during the first few years in order to develop symmetry and to control the head of the tree. Later pruning should be regarded as a corrective process, and resorted to mainly for the purpose of removing broken or crossing branches as well as to maintain symmetry.

Cultivating, Fertilizing and Mulching:—Experience at Beltsville during the last 5 years also indicates that cultivation may be held at a minimum by using orchard grass between the rows, mulching the trees during summer, and applying, each spring, from 2 to 10 pounds of complete fertilizer (5–8–5) to each tree under 10 years of age. The grass is cut twice a season. The first cutting is added to the mulch under the trees and the second is allowed to remain where it falls.

All mulch is removed from the trees at the beginning of winter as a safeguard against providing conditions favorable for mice.

Bearing Ages:—Chestnut trees grow rapidly when conditions are favorable and frequently bear a few nuts when no more than 5 years old. Full crops are not likely before they are 8 to 12 years old.

Pollination:—All evidence to date points to practical self-sterility of the chestnut. Isolated trees occasionally bear a few nuts or even moderate crops, but best results are invariably had only from mixed plantings. This fact, taken alone, argues well for the seedling orchard but in addition to the usual reasons why ungrafted trees are not desirable, size and general character of the nuts may be greatly influenced by the character of the pollen used, as shown by McKay and Crane (2). It is therefore important that not only should there be an abundance of good pollen in the neighborhood, but that there should be an absence of undesirable pollen.

Harvesting Chestnuts and Controlling Insect Pests:—Harvesting should be prompt in order to prepare the nuts for market as soon as possible and also as an important step in controlling certain insect pests. There are certain insects that attack the nuts soon after they fall to the ground, but the weevils, which incubate from eggs deposited inside the nuts, now appear to constitute the greatest natural menace to the chestnut industry over much of the East. The only method of control that has yet been developed is orchard sanitation. Gathering and destroying all infested nuts as promptly as they fall has thus far helped only to the extent of keeping the insects partially in control. However, growing the chestnuts only in well-populated poultry yards has been found to be completely effective in a number of cases.

Chestnuts that are but moderately infested with weevils may be rendered fit for seed purposes by gas or hot water treatment. However, there is no way to make such nuts fit for human consumption.

Sources of Planting Stock

As previously stated, European varieties are being grown on the Pacific Coast. Grafted trees are available from nurseries in that area. Both Chinese and Japanese chestnuts are available both in the East and in the West as seedlings, while seed nuts and grafted trees may be had from several eastern nurseries.

Varieties

The varietal situation has remained virtually in status quo for two years or more. Bigboy, Combale, Fuller, Mayseptjan, and Quercy are the leading European varieties available on the West Coast. Bartlett, Carr, Hobson, Reliable, Stoke, Yankee, and Zimmerman are the principal Chinese varieties. Austin, Murden, Stein, and Vibbert are the present chief representatives of the pure Japanese group. Boone is the best known of the Japanese hybrids that are now grown.

Seedlings

Seedling trees have a considerable and a just claim to attention in the present stage of the industry. All varieties of either Chinese

or Japanese species are still new and comparatively unproved. Such varieties are as yet available from the nurseries to a limited extent only. Grafting is difficult to perform and unions between stock and scion are apt to be non-permanent, and may fail at any time after the grafts have been made until the trees have been in bearing for a number of years.

Seedling trees provide good insurance against inadequate or ineffective pollination and the nuts from such trees are often very fine. It is practically altogether from seedlings that new varieties originate, as none are yet known to have originated as bud sports. Nevertheless, from a financial point of view, it rarely profits an individual to originate a new variety. The ultimate advantages of well-grown grafted trees of rightly chosen varieties are much the same as with other orchard fruits, and standard varieties should be the final goal in every commercial orchard.

Propagation

Propagation of the chestnut by other than seed methods is difficult to perform and, as just explained, uncertain as to permanence of unions. Lack of congeniality between stock and scion is often so great that the latter dies quickly, or lives for only a few months or years. Not infrequently, unions fail after bearing has been under way for several years. Efforts have been made many times to develop a technique by which propagation can be effected by the use of cuttings, but thus far there has been little success in this direction. Layering for two years is successful but too slow and costly to be practical. Apparently the solution to the situation lies in the discovery of stocks and scions which when grafted together will make permanent unions. Grafting below the surface of the ground so as to induce the formation of roots from the scion is a method which may have possibilities.

Summary

From an economic point of view, the time appears ripe for a renewal of interest in chestnut planting. Choice varieties of European parentage are being grown successfully on the Pacific Coast. Equally choice Asiatic varieties, now available from nurseries, are demonstrating their cultural adaptability to climatic and soil conditions in many parts of the country. Rightly selected varieties, so interplanted as to insure adequate cross-pollination, other conditions being favorable, may be expected to produce full crops in from 8 to 12 years after being transplanted. Fall planting gives better results than spring planting except where winters are especially severe; in such regions spring planting is safer. After cutting back sharply at the time of transplanting, pruning should be moderate during both the training and later periods. For five years, cultivation has successfully been held at a minimum at the United States Horticultural Station at Beltsville, Maryland, by use of orchard grass sod between the trees, by maintaining a mulch under the trees during summer, and by applying liberal quantities of a complete fertilizer about the trees each spring. Harvesting should be prompt so as to hasten the nuts to market as early as the demand will justify

and also as a step in controlling certain insect pests. Weevils are considered the most serious natural enemies now attacking the chestnut. Orchard sanitation apparently offers a practicable means of control. Chestnut propagation by asexual methods is difficult to perform and unions are often non-permanent. Further research should bring about stocks and scions which will make congenial and permanent unions when grafted together.

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Effect of Planting Date on Germination of Tung Nuts in the Nursery

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IT IS generally recommended that tung nuts be planted in the nursery in February or March. However, the writers have observed that large numbers of seedlings spring up naturally in tung orchards from fruits that have been missed at harvest time. Sometimes as many as four or five seedlings can be seen growing from a single fruit, suggesting that conditions for germination have been favorable. Although it is common knowledge among tung growers that when nuts are planted in a nursery a considerable number will come up the second year, the planting of year old nuts results in practically a complete failure. There is some evidence that late spring planting impairs germination. These observations indicate a need for more exact information as to the best planting date, the rate at which viability is lost as spring advances, and the effect of planting date on the time required for germination. It is recognized that those nuts that germinate from late plantings grow slowly and produce unsatisfactory seedlings. However, it is not possible to include this phase of the subject in the present paper.

For this experiment open pollinated fruits were saved separately from each of 20 individual tung trees. They were stored as whole fruit in the loft of an unheated garage. The storage temperatures fluctuated widely and on sunny days in May and June were very high. The air dried fruits were soaked in water for 24 hours to facilitate removal of the husks before planting. Sixteen plantings were made from these 20 lots of nuts, at intervals beginning December 5, 1939, and ending July 3, 1940. At each date 600 nuts were planted, 30 from each lot. The nursery was situated on a hillside at the Mississippi Cooperative Tung Farm in Pearl River County, Mississippi, on Bowie soil, which is friable and easy to work. The nuts were planted about 2 inches deep, spaced approximately 14 inches apart in rows 4 feet wide. At any one date the 20 lots of nuts were planted in one block because it was not practicable to divide the planting into two or more replications. The nuts of the various individual trees were always randomized within the block planted at one time. The blocks for the various dates were arranged at random throughout the whole experimental area.

Beginning May 6, weekly counts were made of the stand of seedlings in all lots that had begun to germinate. Strictly speaking, these are records of emergence rather than germination. However, it is believed that few nuts that actually germinated failed to appear above the surface, and the records are termed "germination". It is generally assumed that when planting is done at the usual time, about 60 days are required for germination. Final counts for each lot planted after March 1 were made at about 100 days after planting. Final counts

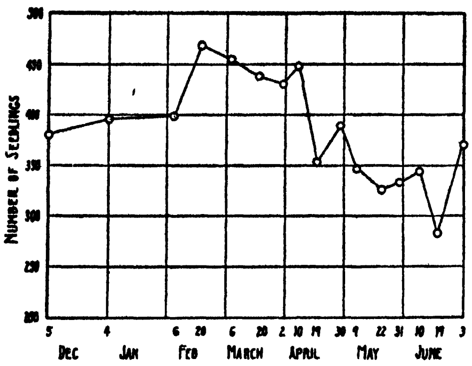

Fig. 1. Number of seedlings resulting from planting lots of 600 tung nuts on each of 16 successive dates.

on all the lots planted in February or earlier, were made late in June, after about 100 days of growing weather. Fig. 1 shows the germination for each of the 16 successive dates. Lack of space precludes including detailed data for each lot of seed. However, the data in Table I show that the differences between dates are statistically significant. The planting made at each date was in a single block; therefore, differences between dates may include some soil effects. This may account for some of the irregularities in the curve shown in Fig. 1. However, on the whole, soil variations within the area used appear to have had a minor effect.

It is to be noted that the best results were obtained in five plantings made between February 20 and April 10, in which the germination ranged from 72 to 78 per cent. Within this period there are no significant differences between dates. Earlier plantings gave a lower germination, those for the plantings on December 5 and January 4 being significantly lower than the results for February 20 and March 6. In general it would appear that although apparently good germination

TABLE I—Number of Seedlings Obtained from Planting 600 Tung Seeds on Each of 16 Different Dates

Date Planted	Number Seedlings Obtained
Feb 20, 1940	468
Mar 6, 1940	455
Apr 10, 1940	448
Mar 20, 1940	438
Apr 2, 1940	430
Feb 6, 1940	398
Jan 4, 1940	395
Apr 30, 1940	387
Dec 5, 1939	378
Jul 3, 1940	369
Apr 19, 1940	354
May 9, 1940	347
Jun 10, 1940	343
May 31, 1940	333
May 22, 1940	326
Jun 19, 1940	282
Difference significant at .05 level	55
Difference significant at .01 level	72

TABLE II—Number of Seedlings Obtained from Planting 480 Seeds Each from 20 Individual Trees

Tree Number	Number Seedlings Obtained
20	418
13	417
15	395
17	381
4	371
10	362
1	359
18	353
16	349
7	333
2	326
8	316
3	299
5	298
11	293
9	292
6	199
19	171
14	125
12	94
Difference significant at .05 level	49
Difference significant at .01 level	64

of nuts in fruits that have been on the ground all winter has been observed in the orchard, fall and winter plantings have no advantage over those made in early spring.

Except for the anomalous result for the planting on July 3, the germination fell off sharply and on the whole rather consistently after April 10. Reference to Table I indicates that in practically every case the germination for the period from April 19 to June 19, inclusive, is significantly lower than that during the optimum period February 20 to April 10. No explanation can be offered for the high germination of nuts planted July 3. The difference between this planting and the one made 10 days before is significant at the .01 level. Nevertheless, it seems to be due merely to coincidence. In August, when this result became apparent, there were no additional nuts from the same lots available. However, a large planting of similar nuts from the same storage gave a low average germination, confirming the trend of the plantings from February to June 19. The conclusion that there is a steady loss in viability appears fully warranted.

The differences in germinating ability of the nuts of the different lots as shown in Table II are extreme. Frost at blossom time may have injured the female flowers of some of the trees, resulting in poor nuts. In some cases the fruit is known to have set even though the nuts contained no embryos. Again, lack of moisture or other local factors may have prevented the nuts on certain trees from filling properly. In addition it is quite possible that the nuts of some trees germinate better than those of others due to inherent factors independent of the local and seasonal environment.

From the weekly counts, it was possible to determine the approximate date on which 75 per cent of the total ultimate germination had occurred. It is believed that the period required to obtain 75 per cent of the total germination is of greater interest than that required for the last seedlings to appear, because in all lots there was a protracted period during which stragglers continued to come up. These data are presented in Fig. 2. It is evident that the rate of germination increased steadily from December to July, as the soil became warmer. From the shape of the curve it appears that the optimum had been attained by midsummer. It is not likely that more rapid germination could have been effected at temperatures higher than those prevailing from June to August. One should not be misled by these data, for although the seedlings came up quickly at high soil temperatures, they

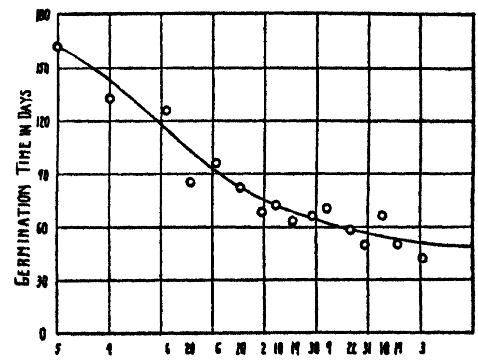

FIG. 2. Time required for germination of tung nuts at 16 successive planting dates.

made very poor growth. Only a few trees large enough for budding or for satisfactory transplanting, were obtained from any of the plantings made later than April 10.

An experiment similar to that just described, but on a smaller scale, was carried out at Cairo, Georgia. In this test 150 mixed nuts, known to have a high percentage of viability, were planted on each of seven dates at approximately 2-week intervals beginning March 15. At each date the planting consisted of three replications of 50 nuts each. When the data from this test were subjected to an analysis of variance, no significant differences were found. The germination of the nuts planted on the first two dates, March 15 and 29, was probably reduced by an early spring drought. Thus it appears that good viability and poor moisture conditions early in the season have in this case given about the same final results as poor viability with adequate moisture late in the season.

Summary and Conclusions

While the results reported in this paper are for only one year, they confirm the practice of most tung growers and there can be little or no doubt that the most advantageous planting season is in early spring, usually late February or March. Since throughout the tung belt late spring droughts occur rather frequently, the early part of the period indicated will no doubt prove better in the long run than planting in late March or early April.

Factors Affecting Time of Initiation and Rate of Development of Pistillate Flowers of the Tung Tree

By LEWIS P. MCCANN, WILLIAM S. COOK, and CHARLES R. CAMPBELL, *U. S. Department of Agriculture, Bogalusa, La.*

ABBOTT (1) has shown that the period through which flower bud initiation in the tung tree may take place is unusually long, extending from May 10 to October 1. Early blossoming predisposes the crop to damage by late frosts, and therefore the whole matter of initiation and development of the blossoms is of much practical importance. The effect of environmental factors on the time of differentiation and the rate of development of the flower buds during the summer is important since the stage attained by the buds at the time of the beginning of dormancy is necessarily dependent upon the activity during the summer. It is possible that the length of the period from inauguration of spring growth to anthesis is dependent upon the degree of development attained before the dormant period.

Most fruit bud studies made by using the paraffin-section technique have necessarily been on small numbers. Rasmussen (4) studied fruit bud formation in apple by taking a sufficiently large sample so that the increasing proportion of differentiated flowers on successive dates could be determined with reasonable accuracy. This was possible through use of free-hand sections mounted in water on a glass slide. In the present study large samples taken on successive dates could be rapidly examined by dissection for determining the stage of development on each date.

Tung trees are commonly monoecious, producing staminate and pistillate flowers on the same tree and within the same bud. The flowers are borne terminally on shoots of the previous season, which average about 30 centimeters in length. New shoots arise, usually in whorls, from growing points that lie within the overwintering terminal bud. The development of the inflorescence within the terminal bud is basipetal, that of the individual flower and its parts is acropetal.

The central and terminal flowers, which develop first, were used as criteria in determining the sex and stage of development of the flower buds examined. A technique of dissection under a binocular dissecting microscope was used to record rapidly the stage of development of a representative sample on each successive date. This was much more rapid than the paraffin method. The buds are large enough to afford easy manipulation for the purpose of removing bud scales. The flower buds within the bud scales are so arranged that calyx tissue, which completely encloses each flower bud, may be removed to determine the stage of development attained by the other flower parts.

For convenience in recording development of the pistillate flower, four arbitrary stages of terminal bud development may be recognized: (a) *Pre-initiation* stage—no evidence of flower development; (b) *Pre-determinate* stage—flower bud initiation is evidenced by the widening and flattening of the meristematic axis and the appearance

of primordia, which eventually form a two or three-parted calyx; (c) *Determinate* stage—pistillate distinguishable from staminate flowers. Stamen primordia are produced in an ascending spiral over the entire face of the central meristematic dome. The carpel primordia appear at the periphery of the dome-shaped meristem; and (d) *Advanced* stage—carpel primordia have developed and the young pistil has the appearance of a lobed and scalloped cup. Within the concavity of the cup the locules make their appearance on the same radii as the convex lobes of the carpels.

The above stages are readily distinguishable in prepared sections under the compound microscope, but when using a dissecting microscope the early predeterminate can not be distinguished with certainty from the pre-initiation stage. Since pistillate flowers can not be distinguished from the staminate flowers until the third stage, the pre-initiation and pre-determinate stages have been thrown together and termed "indeterminate".

Using the dissection method described above, the course of development of the buds was studied in two orchards. Trees in Orchard 1 were 13 years old and those in Orchard 2 were 7 years old. Orchard 1 is located in a frost pocket and had a loss in crop of about 50 to 60 per cent in 1940 because of late spring frosts. The trees in Orchard 2 are rather liberally fertilized, well cultivated, and both summer and winter cover crops are incorporated in the soil each year. Those in Orchard 1 receive much less intensive care and in addition are crowded.

Collections of buds were made weekly from the first week of May to October 4, 1940. A minimum of 20 buds were collected each week from each tree. Care was taken to obtain a random sample, representative of all parts of each tree each week. The buds were fixed and preserved in formalin-acetic-alcohol.

Results and Discussion

Data obtained from dissection studies are presented in Figs. 1 and 2. Collection dates ranging from May 27, 1940 to October 4, 1940 are placed on the abscissas. The number of flower buds falling into each of the three classifications were computed in weekly percentages and are entered on the ordinates of the graphs.

The transition from the vegetative to the reproductive condition set in earlier in Orchard 1 than in Orchard 2. It will be noted in comparing Fig. 1 with Fig. 2 that the curve designating the number of indeterminate buds in Orchard 1 begins to drop at an earlier date than in Orchard 2, June 23 as against July 10, respectively. However, it should also be noted that the rate of change is slower in Orchard 1 than in Orchard 2. The slope of the curve for the former is more gradual, indicating a longer period of time through which the change from the vegetative condition takes place. Correspondingly, the curve representing the percentage of buds attaining the advanced stage of development also rises more gradually and indicates that, as a rule the trees of Orchard 1 required a longer period for the majority of pistillate buds to attain the advanced stage.

Along with the tendency of the flower buds in Orchard 1 to develop

slower, there is also a tendency for fewer buds to develop to the advanced stage during the period from May 27 to October 4. It appears from the empirical curves that in Orchard 2 a slightly higher proportion of the pistillate flowers attain the advanced stage at the end of the season than in Orchard 1.

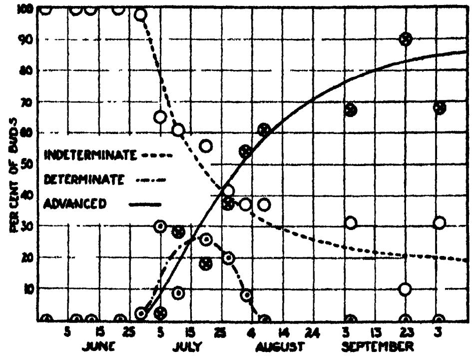

FIG. 1. Empirical curves showing the proportion of tung buds in different stages of development on successive dates under poor cultural conditions (Orchard 1).

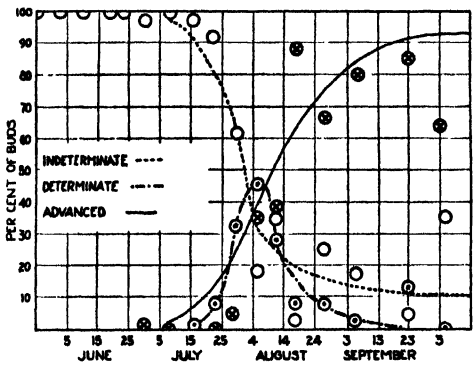

FIG. 2. Empirical curves showing the proportion of tung buds in different stages of development on successive dates under good cultural conditions (Orchard 2).

Although in both orchards there was a prolonged period through which initiation and growth of buds took place, environmental conditions significantly affected the length of the developmental period and the number of pistillate buds produced. It is difficult to analyze these conditions, because the two orchards differ widely in respect to location, culture, crop, and age. These factors are confounded and their interactions make it impossible to discuss the influence of any one factor as a separate entity.

Abbott (1) asserts that a shortage of soil moisture materially hastens the initiation of flower buds of tung. Rasmussen (4) reported both earlier and more abundant fruit bud formation in Baldwin and McIntosh apples in the dry season of 1929 than in the preceding season, in which there was a heavy rainfall. Degman (2) found a similar response in Rome Beauty apple but not in Oldenburg.

The total rainfall during the collecting period, May 27 to October 4, recorded by official rain gauges in each of the two orchards, was about the same, approximately 26 inches. Competition for available moisture must have been more acute in Orchard 1 than in Orchard 2 because of closer planting and the more extensive root systems of the older trees. It is true that the earliest differentiation occurred in Orchard 1, but growth in general was far inferior to that of Orchard 2. Thus it is impossible to say whether the early differentiation is due to the general poor condition of the trees or to the single factor of available moisture.

In fixation each bud was placed in a separate vial, together with a record of the length of the shoot from which it was obtained. This permitted an analysis of the relation of shoot growth to date of initiation and rate of development. As has been reported by Kilby and Parker (3), growth ceased simultaneously in all shoots irrespective of length. Similarly, in each orchard flower bud initiation and development were not correlated with length of shoot growth.

The fact that the greater part of the buds containing pistillate flowers attain the advanced stage of development before entering the dormant period, indicates that the time of flowering in the spring is not affected to any great extent by environmental conditions existing the preceding summer. Thus, the problem of obtaining late-blooming trees to escape late frosts can not be approached from a study of flower bud development prior to dormancy.

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The Growth Period in Shoots and Fruits of Mature Tung Trees

By WILSON W. KILBY and MARVIN D. PARKER, *U. S. Department of Agriculture, Bogalusa, La.*

NO STUDY of the growth periods of shoots and fruits of the mature tung tree has been reported. Knowledge of these may serve as a guide for orchard practice, and in addition their influence on other activities of the tree such as the formation of fruit buds, development of the embryo and filling of the nuts is of considerable interest. Hence in the spring of 1940 an experiment was set up to determine the rate and duration of growth of both shoots and fruits. Since it was thought possible or even likely that a shoot that makes only a short growth might form its terminal buds earlier and hence initiate flowers earlier than one that finally attains a greater length, the work was so planned as to determine whether the growth curves differ for shoots of different ultimate lengths.

The measurements were made on fifteen 7-year-old tung trees in one of the best orchards in southwestern Mississippi. The orchard has received a liberal application of fertilizer annually and both summer and winter cover crops have been incorporated in the soil. Livestock has been kept out of the orchard. The trees are bearing a heavy crop this year.

To eliminate all personal bias, the trees were chosen by first taking row and tree numbers at random, then looking up the trees and using them unless they proved to be dead, broken or replants of a different age.

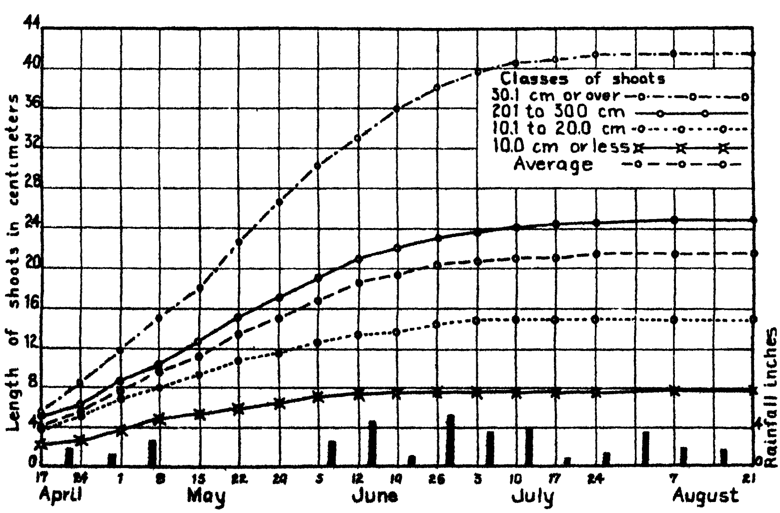

FIG. 1. Growth curves for tung shoots attaining different lengths at the end of the growing season.

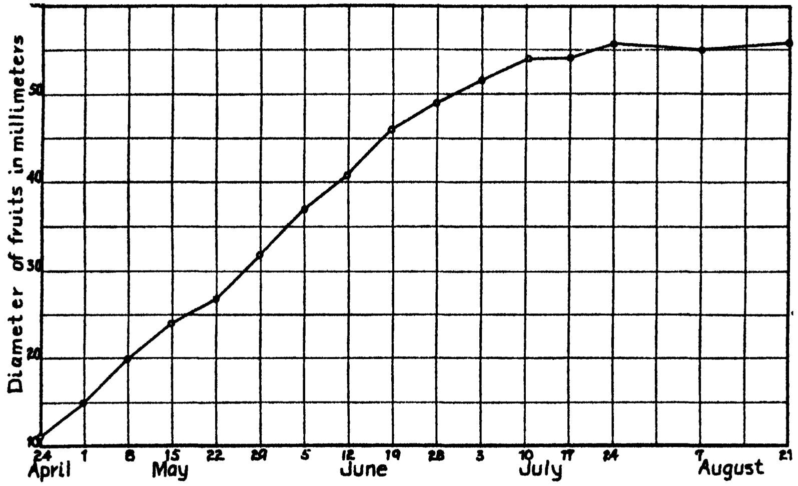

FIG. 2. Growth curve of tung fruits.

To insure getting a representative sample of branches, the bearing area of each tree was divided into eight sections, one high and one low on each of four sides. Within each section on each of the 15 trees one branch was taken at random for measurement. Each of the 274 fruits and 310 current shoots on the 120 branches was individually labeled with a marking tag. These were fastened by making a loop around the shoot or the peduncle of the fruit to eliminate any possibility of girdling.

At weekly intervals from April 17 to July 24, the lengths of the shoots and the diameters of the fruits were measured to the nearest millimeter. In order to eliminate the personal equation as far as possible, the measurements on all dates were made by the same person. Although elongation stopped about July 24, two more measurements were taken at intervals of 2 weeks to make certain that the growth cycle was complete. In tabulating these data the shoots were classified into four groups according to the ultimate length attained; namely, under 10.0 centimeters, 10.1 to 20.0 centimeters, 20.1 to 30.0 centimeters, and 30.1 centimeters or over. The average length attained by each group on each date is given in Fig. 1, together with rainfall records from a station maintained near the orchard by the United States Field Laboratory for Tung Investigations, at Bogalusa, Louisiana.

The growth period of the shoots extended from April 17 to about July 18. Most rapid growth occurred between April 26 and June 6. It is apparent from Fig. 1 that the duration of the growth period for all shoots was the same irrespective of the ultimate length attained. It necessarily follows that the rate of growth, expressed in centimeters per week, was proportional to the final length of the shoot. It is of interest to note that there are but few fluctuations in the rate of growth. A drought that extended from May 7 to June 10 noticeably checked

growth. Throughout the remainder of the growing season there was adequate moisture for normal development.

All the fruits on the branches used for shoot measurements were included in the study. On April 24 they had already attained an average diameter of about 11 millimeters. At blossom time the ovaries of the female flowers vary from 6 to 15 millimeters in diameter. Hence only a little growth could have occurred previous to the first measurement. The average growth rate is shown in Fig. 2.

The period of growth coincides exactly with that of the shoots, and the curve is of the same general sigmoid type. There is no period of arrested development, but increase in size takes place steadily until about the middle of July. Uniformly rapid growth occurred from April till late June.

Period of Stigma Receptivity in Flowers of the Tung Tree

By RALPH T. BROWN, *U. S. Department of Agriculture, Cairo, Ga.*, and ELWOOD FISHER, *U. S. Department of Agriculture, Gainesville, Fla.*

LITTLE work has been done on the technique of tung (*Aleurites fordi*, Hemsl.) pollination. Such studies have been neglected since there has been no apparent problem in obtaining a satisfactory set of fruit and because the improvement of tung to date has been largely by mass selection. With increased activity in tung breeding by state and federal agencies, it is now important to solve the technical difficulties involved.

Knowledge of the period of stigma receptivity is of special importance with tung, a species in which blossoming often extends over a period of a month or more. A long period of receptivity facilitates making crosses between early and late blossoming trees. It also makes it feasible to pollinate a large number of flowers on any individual tree at one time. A knowledge of the period of stigma receptivity may be the means of saving considerable time and expense when parent trees are scattered over distances of 50 miles or more, as is the case in the breeding work of the Division of Fruit and Vegetable Crops and Diseases of the Bureau of Plant Industry.

Realizing how much stigma receptivity and pollen viability in other nut trees are affected by weather conditions (2, 4), the following test was set up to reduce the effect of this factor to a minimum. In an orchard near Cairo, Georgia, April 6, 1940, 10 pistillate flowers on the same seedling tree were covered with 3-pound manila bags. No male flowers were included under the bags. All were bagged in the same stage, which was as soon as the corolla had expanded about ¼ inch beyond the calyx. One flower was pollinated the next day and one each day thereafter, for 9 days. One additional similar series of flowers in the same stage of development was added to the experiment daily up to and including April 16. Thus, flowers of various ages were being pollinated each day from April 7 to April 26 inclusive, and the effect of age of the stigma could be distinguished from that of daily weather conditions. Each series of flowers was on a different tree except that the 4th and 8th were on a single tree and the 10th and 11th on another. The second series is not included in this report as some of the fruits were broken in cultivation. Ten terminals on each of the trees used were bagged for pollen. This was taken from flowers soon after anthesis and applied by touching the stigmas with the dehiscing anthers.

J. R. Cooper (1) reported that the Ben Davis and Delicious apples have greater affinity for pollen of other varieties such as Jonathan or Transparent than for their own, this being shown by faster development of the pollen tubes through the style. Since the situation in tung is unknown, complications due to different pollen-stigma combinations were avoided by self-pollinating all flowers. There was no evidence of self-incompatability in any of the eight trees used in this experi-

ment. Tufts and Philip (3) report that in practically all instances, the almond pollen produced by the first flowers to open is less plentiful and inferior in viability to that of later-opening flowers on the same tree. Not knowing whether this is true of tung, the experiments were not started until a considerable number of staminate flowers had opened.

The method of pollination control used was very effective since no nuts were produced in bagged but unpollinated pistillate flowers. Although some were hanging a month after bagging, they had all dropped by the eighth or ninth week, when the second observation was made.

Of the 10 flowers pollinated in each stage from the time the corolla began to open until it had been open 9 days, there were respectively: 10, 9, 8, 9, 8, 7, 8, 8, 6 and 4 fruits which set and matured. On October 7, these fruits were harvested and the number of nuts in each determined. All fruits harvested had at least one nut, but in getting the array of means in Table I, we counted those flowers which failed to set a fruit as having 0 nuts. Although there is a trend for fewer nuts to be produced per flower pollinated after the corolla had been open 5 days or longer, this difference was not significant until the flowers had been open 8 or 9 days, as is shown in the table. Although the petals dropped 5 or 6 days after anthesis, browning of the stigmas did not begin until the flowers had been open 8 or 9 days, and even then, the stigmas were at least partially receptive, as is further shown in the table.

Additional data for the same season from pollinations made at Gainesville, Florida support the above results. In this work, 2,000 flowers were both cross-pollinated and selfed. Instead of transferring the pollen directly from anther to stigma, the anthers were shelled out of the unopened flowers and allowed to dehisce in open trays. The pollen was then applied to the stigmas with a camel's hair brush. Pollen handled in this way quickly lost its viability, but by using pollen not over 48 hours old, a good set of fruit was obtained from flowers which had been open 5 or 6 days when pollinated. There were not enough data obtained in this test to observe the results of pollinating stigmas of flowers that had been open longer than 6 days.

TABLE I—Array of Mean Differences Showing the Effect of the Age of Stigma at Time of Pollination on the Number of Nuts per Flower Pollinated*

Number of Days Between Anthesis and Pollination	Number of Nuts Per Flower Pollinated	Mean Differences Between Values For Indicated Numbers of Days After Anthesis									
		3	2	1	0	4	5	7	6	8	9
3	4.0	0	.3	.3	.4	.5	.6	1.0	1.3	**2.6**	**3.0**
2	3.7	—	0	0	.1	.2	.3	.7	1.0	**2.3**	**2.7**
1	3.7	—	—	0	.1	.2	.3	.7	1.0	**2.3**	**2.7**
0	3.6	—	—	—	0	.1	.2	.6	.9	**2.2**	**2.6**
4	3.5	—	—	—	—	0	.1	.5	.8	**2.1**	**2.5**
5	3.4	—	—	—	—	—	0	.4	.7	**2.0**	**2.4**
7	3.0	—	—	—	—	—	—	0	.3	*1.6*	**2.0**
6	2.7	—	—	—	—	—	—	—	0	1.3	*1.7*
8	1.4	—	—	—	—	—	—	—	—	0	.4
9	1.0	—	—	—	—	—	—	—	—	—	—

*Mean differences significant at .05 level in italics and those significant at .01 in bold face type.

Although these studies are only preliminary, it is quite evident that under the conditions existing in April, 1940, at Cairo, Georgia, pistillate flowers of tung were receptive from the time the corolla opened until it had been open 9 days. There is a rather wide range in the development of the different flowers on the same tree, therefore, the total period of stigma receptivity for flowers on a tree is probably much longer than the time indicated for a single flower.

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Preliminary Experiments on the Resistance of the Tung Tree to Low Temperature

By Donald L. Fernholz and George F. Potter, *U. S. Department of Agriculture, Bogalusa, La.*

THE Bureau of Plant Industry has recently begun extensive research on tung, *Aleurites fordii*, Hemsl. Resistance to low temperature is one of the important problems to be investigated. In a general way the geographical range of tung indicates its hardiness. It is unable to survive at latitudes adapted to the apple and in regions adapted to citrus there is insufficient cold weather to break its rest period.

In the regions where tung is planted in the states of Texas, Louisiana, Mississippi, Alabama, Georgia and Northern Florida, low temperatures injurious to the blossoms and to the tissues of the tree itself are not uncommon. Early in December, 1938, temperatures of 20 to 22 degrees F killed many young tung trees in Florida orchards. In February, 1939, following a period of warm weather which had forced the trees into active growth, temperatures that ranged between 23 and 25 degrees F occurred throughout the whole tung belt. Flower buds were killed and there was considerable killing back of the twigs. In Florida, where growth activity had been most pronounced, some young trees were killed back almost to the ground. The winter of 1939–40 was the coldest experienced in the South in more than 40 years. Minimum temperatures at weather stations maintained by the United States Field Laboratory for Tung Investigations, Bogalusa, Louisiana, ranged from 8 to 12 degrees F. Trunk splitting, analagous to that which occurs in deciduous fruit orchards in the northern United States, was common. Near Meridian, Mississippi, where the temperature fell to zero, several mature bearing trees were killed outright. At Calhoun, Louisiana, a group of perhaps half a dozen trees 6 or 7 years old withstood a temperature of 3 degrees F with little or no apparent injury. Killing back of branches was fairly common. Throughout the summer of 1940, scattered trees have exhibited symptoms which seem most likely to be due to incipient low temperature injury to the tissues of the trunks and branches.

The experimental studies reported in this paper are in the main artificial freezing tests conducted with the following objects in mind: (a) To determine within broad limits the range in resistance to low temperature of tissues of the tung tree at different seasons of the year; (b) To determine if there are any existing strains of tung that are inherently more resistant to cold than others; and (c) To determine whether the resistance may be modified by fertilizing with nitrogen, phosphorus, potassium, or any combination of these three.

The freezing apparatus consists of a well insulated chamber, refrigerated by a one horse power methyl chloride unit, capable of producing temperatures ranging down to about –10 degrees F. To eliminate radiation effects and insure that the tissues frozen will be chilled solely by a current of cold air, the expansion coils are placed in a compartment separate from the freezing chamber. Electrically operated and thermostatically controlled dampers closely regulate the

flow of cold air from the expansion compartment to the freezing chamber. The operation of the refrigeration unit is also thermostatically controlled so as to maintain the temperature of the expansion compartment at a point roughly ten degrees lower than that desired in the freezing chamber.

The freezing chamber is approximately 4 feet square and 6 feet high. Access is had through a door 3 feet wide by 4 feet high, which permits the freezing of whole trees up to about 5 feet in height. A mercoid thermostat is used for maintaining the chamber at a constant temperature. The rate of temperature fall in the artificial tests is patterned as closely as possible after actual thermograph records taken in the orchards at times when critically low temperatures occurred. During periods of controlled temperature fall the control is switched to a bi-metallic thermostat, similar in its basic design to that described by Smith and Potter (1). After freezing the twigs are placed in glass jars with the lower ends in water and held at room temperature for 3 to 4 weeks before examination. A median longitudinal section of the terminal bud including 4 centimeters of the stem, the region where greatest injury always occurs, was examined under the binocular microscope. On the basis of discoloration observed in the tissues, it was rated on an arbitrary scale on which zero represents no injury and ten indicates that the tissue is completely killed.

Range in Resistance to Low Temperature

The tung is a deciduous tree. In the fall of 1939 most of the leaves had abscised by December 20, following temperatures of 21, 24 and 26 degrees F which had occurred during the preceding 3 weeks. For the tests seedling trees that had at least six lateral branches were used. One branch was retained unfrozen as a control and one each of the

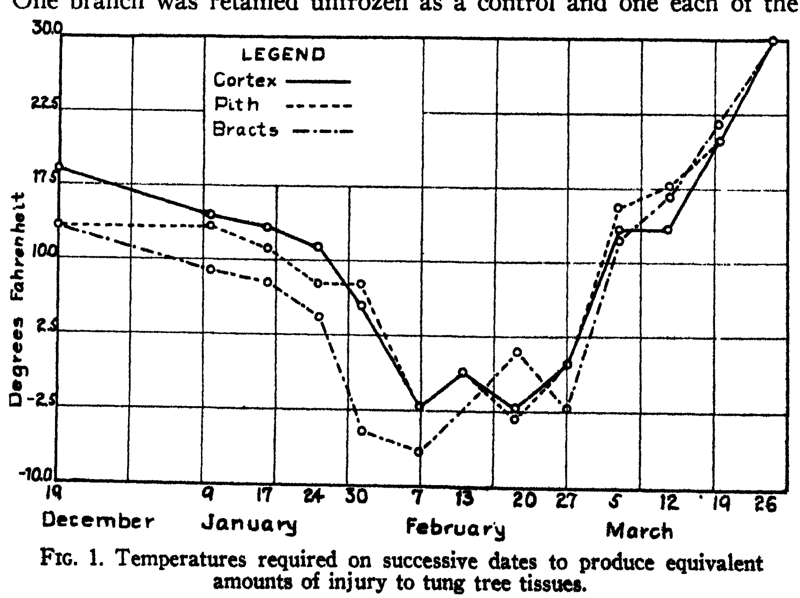

FIG. 1. Temperatures required on successive dates to produce equivalent amounts of injury to tung tree tissues.

other five were exposed to a series of temperatures which it was believed would produce varying degrees of injury. Fourteen tests were conducted at intervals from December 19, 1939 to April 2, 1940, using branches from 10 to 15 different seedling trees on each date. The results are presented graphically in Fig. 1.

The chart very clearly indicates that the tissues of the tung tree steadily increase in cold resistance from the time of leaf fall to midwinter. The degree of resistance attained by the first week in February 1940 was astonishing to the writers. It seems likely that the winter of 1939–40 was such as to induce the maximum cold resistance. Following a warm, dry fall, temperatures during the dormant season gradually became lower until late January, when some of the lowest minima ever recorded in this section of the country were experienced. It is to be noted that the cold wave, which extended over the entire tung belt, coincided with the period of maximum cold resistance in the tree. The state of high cold resistance was maintained well into the month of February but as March approached the trees rapidly became tender and by about the middle of March they were sensitive to temperatures but little below the freezing point.

Inherent Differences in Cold Resistance of Certain Tung Trees

There are at present no commercial varieties or strains of tung trees. In the fall of 1938 open pollinated seed from a considerable number of superior individual trees was gathered and planted. Since it would be inaccurate to use the term "variety", the group of seedlings thus obtained from one individual tree is referred to as a "progeny". During the winter of 1939–40 it was necessary to conduct our freezing tests with seedlings that could be spared from those grown primarily for use in a breeding program. The number of suitably branched trees available from any one progeny was insufficient for conducting tests throughout the entire season. On assembling the results it was found that data on seven different progenies was complete for a series of ten successive tests. Table I gives an analysis of variance for the estimated average injury per twig in the cortical region, in the pith and in the bracts of the stem tips of these seven progenies. These data indicate that there were significant differences in the average injury to the seven progenies on the different dates and also that the average injury for all the tests was significantly less in some progenies than in others. The average injury for each progeny is given in Table II. It is evident from

TABLE I—Analysis of Variance of Data on Cold Resistance of Different Tissues of Seven Tung Progenies

Source of Variation	df	Mean Squares For Data On		
		Cortex	Pith	Bracts
Progenies	6	18.5**	4.1**	5.6**
Dates	9	5.8*	5.8**	12.9**
Error	54	2.6	1.2	1.2

*Significant by odds of more than 19:1 but less than 99:1.
**Significant by odds of more than 99:1.

TABLE II—DIFFERENCES IN COLD RESISTANCE OF THE CORTEX, PITH AND BRACTS AMONG SEEDLING PROGENIES OF INDIVIDUAL TUNG TREES

Progeny of Tree	Average Injury Per Twig		
	Cortex	Pith	Bracts
L-77	1.7	4.5	2.3
F-67	3.0	4.7	3.3
A-34	3.0	3.8	3.2
L-21	4.3	5.3	2.7
L-51	4.5	4.3	3.8
F-120	5.0	4.8	4.3
F-16	5.5	5.7	4.2
Differences significant at the .05 level	1.4	1.0	1.0
Differences significant at the .01 level	1.9	1.3	1.3

Table II that as a rule the seedlings from L-77 are rather resistant. They are clearly more resistant than the seedlings of L-21, L-51, F-16 and F-120. The seedlings of trees F-16 and F-120 were least resistant, being significantly more tender than those of L-77, A-34 and F-67. Table III presents a summary of results including seven additional progenies that were tested in from three to nine of the same freezing tests. The significance levels given are appropriate in every case to the number of tests on which the comparison is based. That there are inherent differences in cold resistance of seedling tung trees seems to be rather well established.

INFLUENCE OF DIFFERENTIAL FERTILIZER TREATMENTS ON COLD RESISTANCE

To determine whether fertilizers applied in the fall have a significant bearing on cold resistance during the ensuing winter, nitrogen, phosphorus and potassium and various combinations of these elements

TABLE III—TUNG TREE PROGENIES THAT EXHIBIT SIGNIFICANT DIFFERENCES IN COLD RESISTANCE

Progeny of Tree	Progenies Significantly Less Resistant					
	Cortex		Bracts		Pith	
	At .01 Level	At .05 Level	At .01 Level	At .05 Level	At .01 Level	At .05 Level
L-77	L-21, L-51, F-16, F-120, F-122, L-52, F-17	L-28, A-21	F-16, F-120, L-51, F-122, F-17	F-67	—	F-16, F-122
L-54	F-122, L-52, F-16	F-120	—	—	—	—
F-67	F-16, F-120, F-122, L-52	L-51	F-122	F-120	—	—
A-34	F-16, F-120, F-122, L-52	L-51	F-122	F-16, F-120	F-16, L-21, F-122	F-120, L-52
A-17	F-122, L-52, F-16	F-120	F-122	F-17	F-122, F-16, L-52, L-21	—
L-28	F-122	L-52	F-122	—	—	—
L-21	F-122	—	F-122, F-16, F-120	L-51, F-17	—	—
L-51	F-122	—	—	—	F-16	L-21, F-122
F-17	F-122	—	—	—	—	F-122
A-21	—	F-122	—	F-122	—	—
L-52	—	—	—	F-122	—	—
F-120	F-122	—	—	—	—	—
F-16	—	F-122	—	—	—	—

TABLE IV—ANALYSIS OF VARIANCE FOR DIFFERENCES IN RESISTANCE OF CORTEX OF SEEDLING TUNG TREES ATTRIBUTED TO DIFFERENTIAL FERTILIZER TREATMENT

Source of Variation	Degrees of Freedom	Mean Square	F Found	F Required at .01 Level
Fertilizers	7	1.95	3.19	2.82
Dates	15	23.91	39.12	2.26
Error	105	0.61	—	—

were applied to seedlings in the nursery on August 29, 1939. Nitrate of soda, muriate of potash, and 18 per cent superphosphate were used as carriers, each at the rate of 400 pounds per acre, whether used alone or in combinations. Each fertilizer treatment was applied to 20 seedling trees of each of seven different progenies selected, not because of any knowledge of their resistance to cold, but because in each case a sufficient number of seedlings was available to carry out the tests. Sixteen freezing tests were made with this material beginning January 16, and continuing at intervals until March 8, 1940. In this case none of the trees had branched, and the top 8 or 10 inches of the trunk were exposed to low temperature, held for 3 to 4 weeks at room temperature, and examined as described above. The data from these tests are given in Tables IV and V. In addition to the individual treatment comparisons given in Table V, it may be calculated that the average rating for the injury of all trees that received nitrogen is 0.6 more than that of the average rating of the four plots that received no nitrogen. On the other hand, the rating for the four plots that received phosphorus is 0.8 less than for the four which received none. Taken individually and in these summaries, there appears to be some evidence that the rather heavy nitrogen treatment was harmful and that some benefit may have accrued from the use of phosphorus. However, since the plots were arranged as best they could be in a nursery planted out for other purposes rather than being set up and replicated in a plot of ground set aside for this particular experiment, it is possible that the results are due to something other than the fertilizing materials used. Further experimentation is needed before definite conclusions can be drawn.

Some additional tests were carried out in which whole trees differentially fertilized, were exposed to low temperature and then replanted

TABLE V—DIFFERENCE IN COLD RESISTANCE OF CORTEX OF SEEDLING TREES ATTRIBUTED TO DIFFERENTIAL FERTILIZER TREATMENTS

Fertilizer Used	Total Injury Per Twig
P	1.7
NP	1.8
K	1.8
NK	2.0
PK	2.2
NPK	2.4
Check	2.5
N	2.6
Difference significant at .05 level	0.6
Difference significant at .01 level	0.7

in the orchard. However, only a small number of trees could be exposed to low temperature by this method and statistical analysis indicates no significant differences due to the treatments.

During the 1940 season it has been possible to set aside between two and three thousand budded trees for artificial freezing tests. The work was begun earlier in the season and fertilizer treatments differing both as to materials and time of application have been used. It is hoped that with this material still more significant results may be obtained during the coming dormant season.

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Important Factors Affecting Peach Tree Longevity in Georgia

By F. F. Cowart,[1] *Citrus Experiment Station, Lake Alfred, Fla.,* and E. F. Savage, *Georgia Experiment Station, Experiment, Ga.*

THE short life span of trees is one of the most important economic problems confronting the peach grower in Georgia. This is especially true in the South Georgia peach section where it is unusual to find orchards 10 or more years of age still having a good stand of trees. In the central section and in the North Georgia mountain section trees are much longer lived. To gain an answer to the underlying causes of the difference in longevity of trees in the various sections as well as to evaluate the causes of tree mortality over the entire area, studies were begun in 1930 and continued through 1940. During this period there has been considerable change in the causes of tree losses due to the development and greater use of new materials for combatting insects. For example, the San Jose scale was causing great losses of trees in the early years of these studies as were also borers, but with the more general use of oil emulsion as a dormant spray for scale and more effective control measures for borers, these sources of loss have greatly decreased. Recognizing that these changes were taking place, more extensive studies on longevity were begun in 1937.

Causes of the Losses

During the years in which these studies were made, the life histories of over 40,000 trees were followed in the three sections of the Georgia peach belt. This present paper represents a summary of the study. The data obtained will be given in complete form in a publication from the Georgia Experiment Station at a later date.

Winter Injury:—Winter injury is the outstanding cause of tree losses in all three peach-growing sections of the state though the form of winter injury predominant is not the same in each section. It is seldom that one sees what might be termed generalized winter injury in Georgia; that is, the trees are killed outright by extreme cold, as quite often happens in the peach-growing sections of the northern states. Winter injury in Georgia is restricted to two major forms, that of crown injury and winter sunscald or southwest injury. Crown injury to peach trees in the South usually results from partial resumption of growth processes during warm periods just preceding subfreezing temperatures. Observations seem to indicate that under these conditions the cambium rather than the phloem and xylem is the tissue killed. Winter sunscald is generally attributed to conditions of high temperature during sunny days followed by sudden drops of temperature to below freezing at night.

Another type of injury which is not a form of winter injury but is

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very closely related to it in its effect on the trees is one known as summer sunscald. Summer sunscald occurs in the south and central peach sections with damage to the scaffold branches and trunk due to the high temperatures developed by the direct rays of the sun during the summer months. This injury results where the trees are so severely pruned that the main branches and trunk are not protected by foliage. It is mentioned at this point so that the two types of sunscald may not be confused.

In South Georgia crown injury is the predominant form. The climate of this section is naturally favorable for this type of injury. In North Georgia winter sunscald is quite common causing serious tree losses particularly on the southern and southwestern slopes. In this area crown injury is not often found since at these higher altitudes the climate is not conducive to such injury. In North Georgia trees even fairly badly injured by winter sunscald, if located on fairly level land, continued to live and maintain production while on the more abrupt slopes, trees with the same amount of injury died rapidly. This evidences that there are other factors complicating the situation rather than its being a simple case of winter injury. In these areas of greater tree losses, the slope is more abrupt making for a much greater run-off of water. On the steeper slopes, erosion has reduced the volume of soil into which the roots may penetrate easily. Thus the combination of factors of high percentage run-off of rainfall, less volume of soil to hold water plus the injured xylem which is usually incapable of conducting water, all operate to cause the death of trees in such locations.

Borers:—Borers do not account for the heavy losses of peach trees that they did in former years. This condition is, no doubt, largely a result of the development and general use of more effective control measures. Even with these control measures, injury caused by borers is still an important factor affecting longevity. Borers cause more damage in the South than in the North Georgia peach section since there is a greater period of the year in South Georgia in which the temperature is high enough that these insects can maintain maximum activity and do more damage over the longer period.

Erosion:—Erosion ranks with or slightly ahead of the peach tree borer as a cause of tree losses although it is most difficult to give an estimate of the loss due to this cause. A large portion of the commercial peach belt of Georgia is characterized by heavy red soils through which the roots of the peach penetrate comparatively slowly. If the top soil through which the roots penetrate most easily is eroded, the volume of soil occupied by the roots is quite restricted as is also the length of life of the tree. There is a great difference in the growth of trees on land not eroded and on land which has been but slightly eroded in the same orchard. On side hills with an 8 to 10 per cent slope where no effort has been made to conserve water and soil, it is rather interesting to note how rapidly the trees die compared with trees on less abrupt side hills. In one section of a 9-year-old orchard in which the slope was 2 to 3 per cent, 76.9 per cent were in good condition, while on 8 to 10 per cent slope, only 55.9 per cent of the trees remained.

Soils:—These studies indicate that particular attention should be given to soils in which the peach orchards are to be planted. There is a wide variation in growth response favorable to tree longevity which seems on observation to be correlated with soil type, its inherent fertility, and its erodable condition. The problem of soil drainage except in very localized areas is not of as great importance in Georgia as in some sections of the country. The prevailing high temperatures prevent to a large extent waterlogging of the soil which might occur in regions of lower mean temperatures and higher rainfall.

Phony Disease:—It was once thought that this disease would become an important factor affecting the longevity of the peach especially in South Georgia. Due to excellent eradication work carried out each year, the losses from this disease have been minimized.

In figures obtained from the Bureau of Entomology and Plant Quarantine for the three-year period 1938 to 1940, the North Georgia peach section showed 68 infected trees out of 882,900 or .008 per cent, the Central Georgia peach section had 30,706 infected trees out of 3,349,-470 or 0.92 per cent, while in the South Georgia peach section where the disease is most prevalent, there were 134,168 infected trees out of a total of 7,725,508 inspected trees or 1.74 per cent.

Crown Gall:—Crown gall was found commonly in the orchards examined. It is not often the sole cause of death, but it is usually a contributing factor. It occasionally causes serious economic loss with young trees especially in those orchards where careless cultivation has caused wounding of the trees at the ground level.

Nematodes:—Nematodes cause the loss of but few trees in Central and North Georgia where the soils are heavy. In South Georgia where the lighter textured soils are found, much more nematode injury occurs. In the future, with the reduction in cost of the Shalil and Yunnan nematode-resistant stocks unless some unforseen difficulty arises, more orchards will be set to trees budded on these stocks, and nematode injury should become a less important factor in limiting the life of peach trees.

Prolonged Dormancy:—In the southern part of Georgia, prolonged dormancy or delayed foliation due to insufficient hours of cold below 45 degrees F is a factor in longevity with some varieties. It should be pointed out that conditions favorable for prolonged dormancy of peach trees are of unusual rather than of common occurrence in most of the commercial peach growing area of Georgia. The cumulative effect where such conditions occur frequently undoubtedly results in a shorter life span of the trees, but the infrequency of delay in foliation of peach trees over most of the commercial peach belt of Georgia relegates this condition to a role of comparatively minor importance as a factor affecting longevity.

Varieties:—It is recognized by most growers that trees of some varieties are longer lived than others. The Mayflower and Early Rose varieties are generally considered weak trees and are more susceptible to winter injury than are Elberta and some other varieties. This generalization is borne out by figures obtained in this study. In an 11-year-old orchard of an original 5,000 Early Rose trees, 3,050 or 61 per

cent were living, of 5,000 Georgia Belle trees, 4,300 or 86 per cent were in good condition, and of 9,781 Elberta trees, 8,118 or 83 per cent were alive.

Discussion

The susceptibility of trees to injuries of various types and their vitality after such injury is chiefly dependent on the tree condition when subjected to such rigors. Climatological data seem to furnish the most plausible explanation for the more favorable tree condition and the longer span of life of peach trees in the more northern sections of the Georgia peach belt as compared to the more southern sections.

The South Georgia section had an average mean temperature over the 10-year period 1930 to 1940 of 4.7 degrees F higher than that of North Georgia. During the critical months of the growing season, April through September, the average temperature is 4.2 degrees F higher in South than in North Georgia. The average annual rainfall for the 10-year period is 13.85 inches more in the north section than in the south, while during the period of greatest water use, April through September, 4.53 inches more rainfall fell in North Georgia. With the lower mean temperatures which result in decreased transpiration and evaporation rates, together with the greater annual rainfall in North Georgia, the orchards in this district where some effort has been made to prevent excess run-off enter the season of hot weather with a greater reservoir of water and maintain this reserve better than the orchards farther south.

In the peach-growing sections of the northern states and even in North Georgia where high temperatures do not prevail over so extensive a period, longer lived orchards are to be expected. In North Georgia where the moisture supply is more nearly adequate at all times, even fairly badly injured trees live and maintain production over several years as is true in some northern states. In South Georgia the competition for water of the different parts of the tree is so heavy that injury to one side of the tree soon results in its death. Under these conditions of high temperature and often times inadequate water supply, any injury no matter how slight quickly weakens the tree, making it even more susceptible to winter injury and the attacks of insects and diseases.

Further Studies on Identification of Peach Varieties by Leaf Characteristics[1]

By E. M. Meader, *U. S. Department of Agriculture*, and
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A PRELIMINARY study of leaf blade characters of the peach by Sefick and Blake (4) and a progress report by Meader and Blake (2) have indicated the value of measurable leaf characteristics of the peach for identification of varieties. Observations upon measurable leaf characteristics, namely, width-to-length (W/L) ratio, base angle, and apex angle, have been continued to determine the variability of these leaf characteristics of varieties when grown at several points widely separated geographically.

Locations

Samples of leaves of each of the eight varieties listed in Table I were obtained from at least three locations. So far as available, leaves of these varieties were secured from orchards of each of the following institutions: United States Horticultural Station, Beltsville, Maryland and field station at Fort Valley, Georgia; New Jersey Agricultural Experiment Station, New Brunswick, New Jersey; Horticultural Experiment Station, Vineland Station, Ontario, Canada, and New York State Agricultural Experiment Station, Geneva, New York.[2] Leaves of only one variety, Elberta, were obtainable at all five locations. Samples of leaves 6 to 7 inches long and 5 to 6 inches long were collected from each variety at all of the locations except Fort Valley, Georgia.

Measurement of Samples

The length and maximum width of a leaf blade and its apex and base angles were measured upon a newly-designed foliarmetric gauge, which will be described elsewhere (3), and according to specifications previously described (4, 2).

Ten leaves taken at random from each of the samples of 6- to 7-inch and 5- to 6-inch criterion leaves which had been collected at the several locations were measured in a green state as soon as possible after collection rather than dry after having been pressed between herbarium blotters as in previous studies.

Discussion of Data

Since measurements of samples of 5- to 6-inch leaves taken at four of the five locations confirmed the earlier conclusion (2): that the smaller leaves give less reliable data upon measurable leaf character-

[1]The detailed measurements of leaf samples and compilation of data necessary for accomplishment of this study were made possible by personnel provided by the Work Projects Administration under official Project No. 65–1–22–477.

[2]The authors are indebted to Mr. D. H. Scott and Dr. J. H. Weinberger of the U. S. Bureau of Plant Industry, Dr. W. H. Upshall of Vineland Station, Ontario, and Dr. George Oberle and Mr. L. F. Hough of Geneva, N. Y. for their kind assistance in collecting leaf samples at their respective locations.

TABLE I—A COMPARISON OF LEAF MEASUREMENTS OF EIGHT PEACH VARIETIES

1940 Location	6- To 7-Inch Green Leaves					
	Class*	Mean W/L Ratio (Per Cent)	Class†	Mean Base Angle At 0.5 Inch (Degrees)	Class‡	Mean Apex Angle At 1 Inch (Degrees)
Hiley—White Flesh—Reniform Glands						
Fort Valley, Ga.	1	19.8	2	65	2	28
Beltsville, Md.	2	21.4	2	71	3	32
New Brunswick, N. J.	2	21.9	2	67	3	31
Raritan Rose—White Flesh—Reniform Glands						
Fort Valley, Ga.	2	21.7	3	78	2	28
Beltsville, Md.	2	22.9	3	77	3	30
New Brunswick, N. J.	2	23.8	3	80	3	31
Geneva, N. Y.	2	22.8	4	86	3	31
Valiant—Yellow Flesh—Reniform Glands						
New Brunswick, N. J.	2	22.9	2	74	2	29
Vineland, Ontario	2	23.4	3	76	3	30
Geneva, N. Y.	2	22.4	3	76	3	30
Vedette—Yellow Flesh—Reniform Glands						
New Brunswick, N. J.	3	25.6	3	84	2	27
Vineland, Ontario	2	24.9	3	82	2	28
Geneva, N. Y.	3	26.3	4	89	2	29
Candoka—Yellow Flesh—Reniform Glands						
Beltsville, Md.	2	24.2	3	75	3	30
New Brunswick, N. J.	2	24.5	3	78	2	29
Vineland, Ontario	3	25.8	3	80	3	31
Geneva, N. Y.	3	25.2	4	88	3	30
Elberta—Yellow Flesh—Reniform Glands						
Fort Valley, Ga.	3	25.1	3	82	3	31
Beltsville, Md.	2	24.6	3	82	3	32
New Brunswick, N. J.	3	25.5	4	88	3	30
Vineland, Ontario	3	25.8	4	88	4	37
Geneva, N. Y.	3	25.9	4	89	3	34
Golden Jubilee—Yellow Flesh—Reniform Glands						
Fort Valley, Ga.	3	25.2	3	83	2	28
Beltsville, Md.	3	26.7	4	88	3	33
New Brunswick, N. J.	3	27.0	4	89	2	29
Geneva, N. Y.	3	26.3	4	92	3	33
Hardee—Yellow Flesh—Reniform Glands						
Beltsville, Md.	3	29.0	4	94	3	33
New Brunswick, N. J.	3	28.8	4	96	3	31
Vineland, Ontario	3	28.4	4	97	4	35
Geneva, N. Y.	4	33.3	4	102	4	37

*W/L ratio classes: 1 = very narrow, 19.9 and less, 2 = narrow, 20.0 to 24.9, 3 = medium, 25.0 to 29.9, 4 = broad, 30.0 and above.
†Base angle classes: 2 = acute, 60 to 74 degrees, 3 = broadly acute, 75 to 84 degrees, 4 = obtuse, 85 degrees and above.
‡Apex angle classes: 2 = sharply acute, 25 to 29 degrees, 3 = acute, 30 to 34 degrees, 4 = broadly acute, 35 to 39 degrees.

istics than leaves 6- to 7-inches long,— only data upon 6- to 7-inch leaves are given in Table I. These data on W/L ratios, base and apex angles are mean values based on measurements of 10 green leaves.

Width-to-Length Ratios:—Mean W/L ratios of leaf samples of a given variety taken at the several locations fall in the same size classes or are close to the arbitrary divisional points of the size classes except for the sample of Hardee taken at Geneva, New York. In this leaf sample, the W/L ratio is over 4 per cent greater than that of any of the samples taken at three other locations. The W/L ratios of leaf

samples of Hardee taken at these other three locations are in good agreement.

Base Angles:—The arbitrary divisional points of the size classes for leaf base angles are 65, 75 and 85 degrees. When allowance for differences caused by arbitrary class divisional points is considered, the mean base angles of the leaf samples of each variety from the several locations fall in the same base-angle size classes with one or two notable exceptions.

The base angles of leaves of most varieties studied in 1940 when grown at Geneva, New York tended to be broader than the same variety from other locations.

In Elberta, base angles of leaf samples from Fort Valley, Georgia and Beltsville, Maryland are the same; while those from the three more northern locations are the same. However, these values for leaves from the three more northern locations were significantly greater than those from the two more southern locations.

In a comparison between varieties, the differences between the mean base angles of Elberta and Hardee at four locations are as follows: at Beltsville, Maryland, 12 degrees; at New Brunswick, New Jersey, 8 degrees; at Vineland Station, Ontario, Canada, 9 degrees; and at Geneva, New York, 13 degrees. At all four locations, the base angle of leaves of Hardee is approximately 10 degrees broader than that of Elberta. In a similar comparison between Elberta and Golden Jubilee, there is an apparent difference in the base angles of samples of leaves of the two varieties at Beltsville, Maryland, but no appreciable base-angle difference at three other locations. Golden Jubilee resulted from a cross of Elberta by Greensboro. It is of interest to note how closely Golden Jubilee corresponds to Elberta in measurable leaf characteristics at each of the locations except Beltsville, Maryland.

Apex Angles:—With several exceptions that are to be mentioned, mean apex angles of leaf samples from the several locations fall in the same size classes or differ in class because of arbitrary class divisional points, which are at 25, 30, and 35 degrees. In both Elberta and Hardee, the apex angles of leaf samples from Vineland Station, Ontario, Canada and Geneva, New York tended to be slightly broader than samples of these varieties taken at the other locations. A tendency for the apex angle to be slightly narrower in leaf samples taken at Fort Valley, Georgia than in those from more northern locations may be noted in Hiley, Raritan Rose, and Golden Jubilee. No comparisons of differences in mean apex angles between two varieties at one location with the same two varieties at another location will be made since all of these varieties have mean apex angles that fall in Class 3 at most of the five locations.

In an interpretation of these data, the facts that leaf samples were taken by different men at the several locations and that only ten leaves from each sample were measured to give the mean values presented in Table I should be considered.

Growth Status of Trees:—The authors observed the trees and selected leaf samples at Geneva, New York. The trees had made a vigorous but compact growth the previous year, apparently influenced

by a relatively dry summer. When observed in August 1940, the trees were making a good growth, but the twigs were relatively thick and the leaves vigorous and leathery. The green fruits were exceptionally large for the variety and season. Such a quality of growth is associated with a high reserve of carbohydrates for the period. Observations in New Jersey have indicated that the foliage upon trees of this growth status tend to be thick and leathery and to be characterized by relatively broader base angles than leaves upon trees which are making a more rapid and succulent growth.

Conclusions from Data Presented:—Leaves, having blades 6 to 7 inches long, selected from the mid-portion of vigorous terminal shoots of fruiting trees of the peach have continued to give more reliable data upon measurable leaf characteristics than did 5- to 6-inch leaves when samples of both sizes were selected in a similar manner at four points which are widely separated geographically. Close agreement in measurable leaf characteristics was found between Beltsville, Maryland and New Brunswick, New Jersey for all varieties studied in 1940 with the exception of the base angle of Elberta at the two locations. When samples of 6- to 7-inch leaves of peach varieties were selected for comparison from several locations which are widely separated geographically, width-to-length ratio was found to be the most constant of the three measurable leaf characteristics, here studied. Each of the eight varieties studied tended to fall in the same size classes for the leaf characteristics of the variety at all of the locations from which samples were available with several exceptions as may be noted in Table I. When there was a recognizable difference between the foliage of two varieties at one location, a similar relative difference between the same two varieties was found at the other locations.

Value of Measurable Leaf Characteristics

Measurable leaf characteristics are valuable for describing the foliage of peach varieties with mathematical precision according to the size classes and accompanying terminology (see Table I) established by Sefick and Blake (4) and applied by Lesley (1) to several new varieties.

When there are class differences between two varieties in anyone of their three measurable leaf characteristics, if only these two varieties are to be considered, they can be separated by leaf measurements. For example, Valiant and Vedette both produce yellow-fleshed fruits very similar in form and appearance which ripen at the same time and are hardly distinguished at New Brunswick, New Jersey. Both varieties have reniform foliar glands. They can be separated, however, by a distinct difference in the size of the base angle of their leaves (see Fig. 1). The base angle of Valiant is Class 2; that of Vedette is Class 3. Similarly, Elberta can be told from Hardee (see Fig. 1) at any of the several locations by a marked difference in width-to-length ratios and base angles of their leaves.

A number of varieties fall in the same size classes for measurable leaf characteristics. Such varieties cannot be differentiated by leaf measurements. For example, Valiant and Candoka both have values

for leaf characteristics so close that they could not be told apart by this method.

Differentiation of Varieties by Leaf Outlines:—The foliage of two varieties with the same measurements may be quite different in form. A leaf of Valiant (see Fig. 2) has its point of maximum width below the mid-point of the length of the blade and then tapers gradually to its apex; whereas, a leaf of Candoka has approximately the same width for the greater portion of its length and then tapers sharply to its apex. The outline of leaves can be used to supplement measurable leaf characteristics in the identification of varieties if pressed specimens of the foliage are prepared. These may be compared with a leaf herbarium composed of contact photographic prints of typical leaves of varieties. Certain varieties are so much alike in all respects that they cannot be differentiated by the outlines of their leaves; for example, Elberta and Golden Jubilee (Fig. 2).

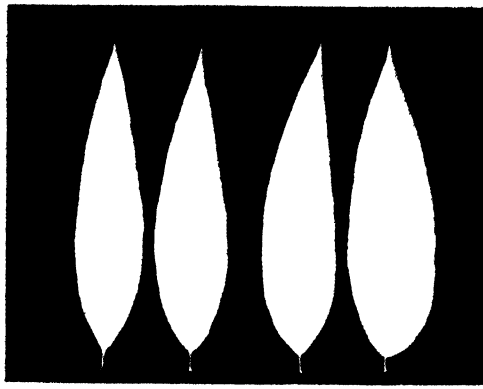

FIG. 1. Contact photographic print (one-quarter actual size) of typical pressed peach leaves: Valiant (left), Vedette (center), Elberta (center), and Hardee (right).

It often happens that when fruits of an unknown variety are to be identified, the varieties which they most resemble can be narrowed down to two or three by reference to plant characters such as tree types, flower types, time of ripening fruit, and fruit and pit characters. In such cases, criteria furnished by leaves of the varieties may be especially valuable for identification purposes.

The authors suggest that measurable leaf characteristics and leaf outlines be used in conjunction with and to supplement other useful criteria commonly employed in identification of peach varieties.

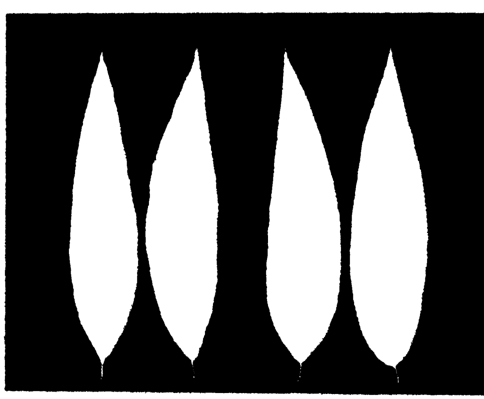

FIG. 2. Contact photographic print (one-quarter actual size) of typical pressed peach leaves: Valiant (left), Candoka (center), Elberta (center), and Golden Jubilee (right).

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Split-Pit of Peaches
Estimation of Time When Splitting Occurs

By L. D. Davis, *University of California, Davis, Calif.*

AN ESTIMATION of the time when splitting occurs should be of value in an analysis of the factors causing or contributing to the split-pit condition. Blake (1) has reported that splitting takes place early in the season before the pits have hardened. Miki (2) has reported that the split-pit phenomenon occurs twice during the development of the fruit. The first splitting is reported to occur about 20 days after full bloom while the pit is yet soft. Splitting of this type is usually accompanied by the formation of callus tissue. The second splitting, occurring through the plane of the suture, is reported to occur during the time when the stone is hardening. This is the split-pit found at harvest, the one economically important, and is the one considered in this investigation. Miki has reported that both types may occur in a single fruit.

It is a common observation that most fruits with split-pits have a larger cross (cheek to cheek) diameter in relation to the suture diameter than do unsplit peaches. Both Blake and Miki have reported that these dimensional differences may occur a considerable time before the fruit is mature.

The investigations reported in this paper were conducted from 1937 through 1940. In general 50 to 60 fruits on one tree were tagged 1 to 3 weeks before the pit began to harden on the tip: measurements of the suture and cross diameters of each fruit were made at weekly intervals until maturity. The maximum loss of fruits during any season was 10 out of 50 originally tagged, and frequently but one or two would be lost. A record of the split-pit condition of each fruit was made at harvest. The measurements for the entire season were

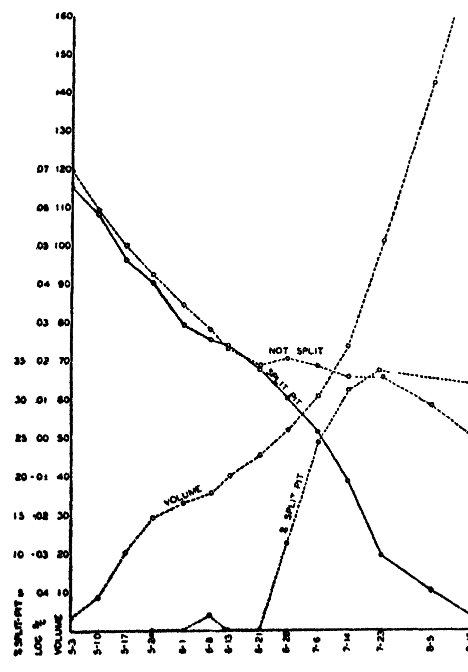

Fig. 1. Logarithm of S/C calculated from average size of split and unsplit fruit; volume in cubic centimeters calculated from the suture diameter and per cent split-pit in random samples (Elberta 1937).

TABLE I—AVERAGE SIZE (MM) OF THE SUTURE AND CROSS DIAMETERS OF PEACHES THAT WERE AND WERE NOT SPLIT

	1937		1938		1939		1930	
	Split	Not Split	Split	Not Split	Split	Not Split	Split	Not Split
Average suture diameter, 1st measurement................	27.9	27.3	27.0	26.7	30.3	29.8	36.7	35.8
Average suture diameter, last measurement................	66.7	68.2	65.7	66.6	60.5	61.8	67.9	68.3
Average cross diameter, 1st measurement................	24.4	23.8	23.4	22.7	27.0	26.2	33.1	31.6
Average cross diameter, last measurement................	72.7	67.0	71.0	65.5	63.8	59.8	73.2	66.9

divided into split and non-split groups and calculations made from these two groups. The number of split-pits varied from 1 to 36. During the four years 49 lots comprising 13 varieties were investigated.

Table I presents the data for the average size of the suture and cross diameters of fruits that were and were not spilt, 1937 through 1940. The suture and cross diameters were consistently larger in the split-pit fruits at the first measurements than in the non-split, although the differences were small. At the last measurement the suture diameter was smaller in the split-pit than in the non-split and the cross diameter was considerably larger among the split-pit fruits. The data for the average values are substantiated by that of the individual lots. Thus, out of a total of 49 comparisons, at the first measurement, the split-pit fruits were larger than the non-split in 35 cases for the suture diameter and 39 cases for the cross-diameter. At the last measurement the split-pit fruits were larger than the non-split in only 17 cases in the suture diameter but were

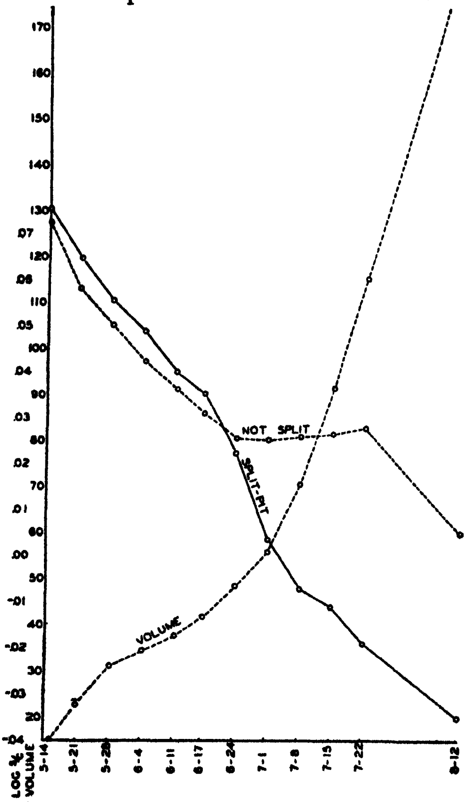

FIG. 2. Logarithm of S/C calculated from average size of split and unsplit fruit; volume in cubic centimeters calculated from the suture diameter (Elberta 1938).

larger in 46 cases in the cross diameter.

Preliminary investigations were made of the time when splitting occurred by collecting random samples at frequent intervals beginning early in the season and examining the condition of the pit. The presence of splitting was determined by making cross sections through the basal and distal ends with a knife. It was learned that the incidence of splitting occurs quite rapidly. Thus consecutive samplings would show zero split-pit then suddenly the next sample would show a relatively high percentage of splitting which would increase for a few samplings. It seems that if splitting occurs suddenly, as these preliminary investigations indicated, and if the splitting were reflected in the relative sizes of the cross and suture diameters that these might furnish the basis of a procedure for investigating the time of occurrence of splitting in tagged and measured fruits. The situation shown in Table I is favorable for a comparison of the values of the ratio of suture to cross diameter in the two groups of fruits since the suture diameter grows less rapidly in split-pit than in non-split and the cross diameter more rapidly at some time during the seasonal development, thus accentuating the differences between the relative values of the two diameters.

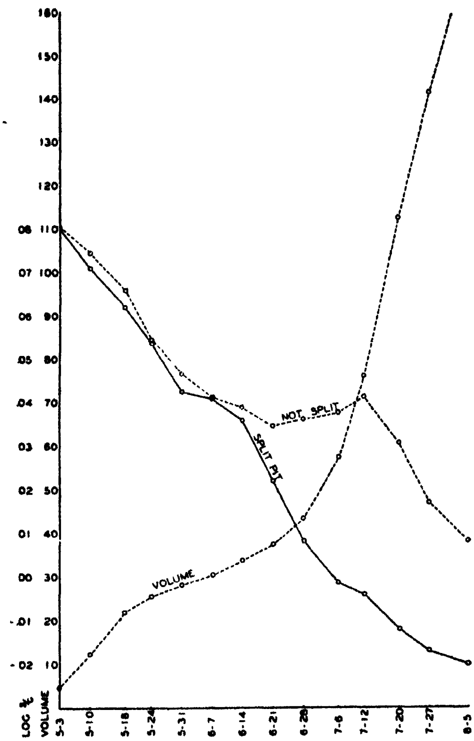

FIG. 3. Logarithm of S/C calculated from average size of split and unsplit fruit; volume in cubic centimeters calculated from the suture diameter (Paloro 1938).

Figs. 1 to 5 show the ratio of the average sizes of the suture and cross diameters of split and non-split fruit, in which the logarithm of the ratio is plotted against time. The character of the seasonal changes in the S/C of non-split fruit needs consideration in interpretation of the behavior of these ratios of split-pit fruits. The cross diameter grows more rapidly than the suture, causing the value of S/C to regularly decrease from the time of the first measurement until sometime after the pit has begun to harden on the tip when the value suddenly ceases to decrease. The suture and cross diameters then

may grow at the same rate for a period as in Fig. 1 for Elberta or the suture may grow more rapidly than the cross as in Fig. 4 for Paloro. Finally, the cross diameter grows much more rapidly than the suture and S/C slopes steeply down. All the investigations have not shown as steep a downward slope as is illustrated in the figures. In some cases the downward slope has been almost lacking. Enough information is not available to know whether this variation is a varietal characteristic or one that may occur within a variety. The seasonal values of S/C for non-split fruit can be divided into three parts. The first in which the values regularly decrease, the second in which they remain constant or may increase and the third in which they may decrease.

The behavior of S/C for split-pit fruits is also shown in Figs. 1 to 5. They show the same early seasonal behavior as do those for non-split fruit and are either almost parallel or identical with them. The subsequent behavior of the split-pit fruits differs sharply from that of the non-split. The slope of the former group suddenly becomes very steep downward and continues for the remainder of the season. In some cases, such as Fig. 2 for Elberta in 1938, the downward slope of the early phase becomes a steeper downward slope. Or the slope may become less steep for a few days as in Fig. 3, then suddenly become steep downward or the slope may change to an upward one as in Figs. 4 and 5, and then abruptly become steep downward. The latter two cases, Figs. 3, 4 and 5, show a more gentle or upward slope that extends over but one measuring period. Other investigations have shown, however, that this period may be longer than those illustrated.

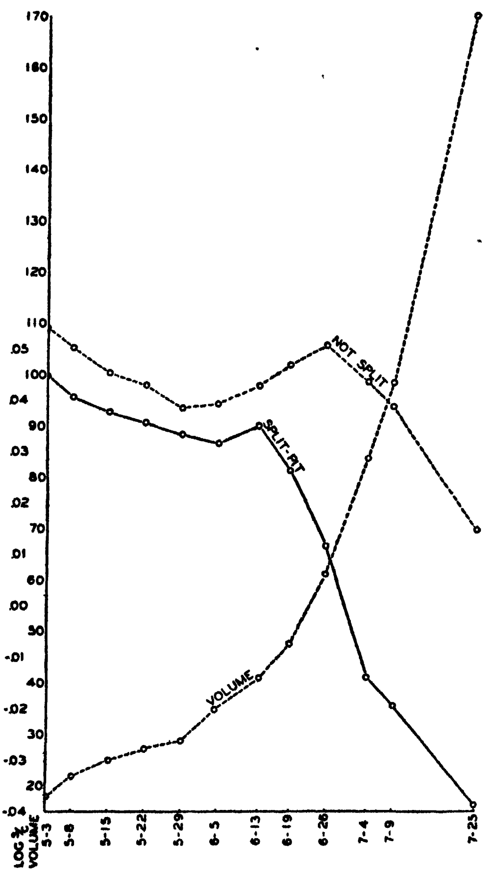

FIG. 4. Logarithm of S/C calculated from average size of split and unsplit fruit; volume in cubic centimeters calculated from the suture diameter (Paloro 1940).

The divergence of the

curves for split and non-split may be interpreted as the time when splitting begins, that is, as the time when the pit is cracked and the cross diameter abruptly increases its size. In 1937, in order to verify this assumption regarding the time of splitting, random samples of 150 fruits were taken concurrently from trees similar to that on which the fruits were measured. The pits were examined and the percentage of split-pit calculated for each of the 10 lots investigated in that year. Figs. 1 and 5 show the percentage of split-pit in the Elberta and Tuscan samples. The last sample is the amount of split-pit in the lot of trees under investigation as determined at harvest and shows how representative the random samples were. There was good agreement in all cases between the time when splitting occurred as shown by the divergence of the curves and that shown by the random samples.

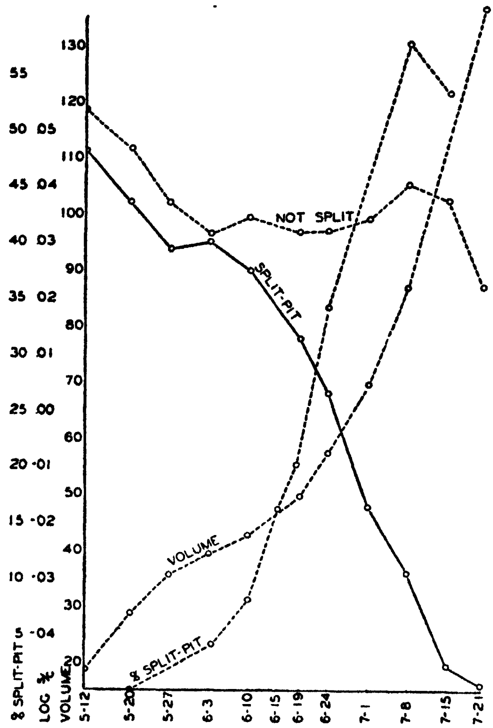

FIG. 5. Logarithm of S/C calculated from average size of split and unsplit fruit; volume in cubic centimeters calculated from the suture diameter and per cent split-pit in random samples (Tuscan 1937).

The success of the method would depend upon the following conditions: (a) that peaches that would and would not split have similar relations between the suture and cross diameters early in the season; (b) that the relative changes in the diameters of the two groups before splitting be much the same; (c) that splitting be suddenly reflected in the relative sizes of the two diameters, and (d) that there be reasonable agreement between this method and adequate random sampling regarding the time when splitting occurred. Figs. 1 to 5 show that these conditions have been fulfilled.

The data presented in this paper show average sizes of the two diameters. Since all fruits do not split on the same date, the slope of the split-pit curve is the result of the average sizes of split and unsplit fruit until such a time as all the individuals are split; the slope therefore would not be so steep when it was conditioned by a mixture of split and unsplit fruit. In addition the use of averages does not indicate

the period of time over which splitting has taken place. The data for individual fruits may however, be studied. This analysis of individual fruits indicates the period during which the fruits have split and it also shows how abruptly the direction of the S/C curve changes when splitting has occurred.

The volumes of the unsplit fruit calculated from the suture diameter, are also shown in each of the figures. Comparisons may thus be made between the growth cycles of the fruit and the behavior of the S/C curves of both split and unsplit fruit.

In 1937 pit hardening in Tuscan and Elberta, as determined by cutting fruits in the field, began about May 27. The change of slope of the S/C curve for non-split fruit in Tuscan (Fig. 5) began about June 3, seven days later, while in Elberta (Fig. 1) it began about June 21, 25 days later.

In 1938 pit-hardening began in Elberta about May 30 and in Paloro about May 26. The changes in the S/C curve of non-split fruit occurred in this year about 25 days after pit hardening (Figs. 2 and 3). In 1940 pit-hardening began in Paloro about May 8 and the change in the S/C curve of non-split fruit about May 29, 21 days later (Fig. 4).

Splitting, as shown by these data, has always occurred after pit-hardening has begun but at varying intervals. In Tuscan (Fig. 5) it began about 7 days later; in Elberta (Figs. 1 and 2) about 20 days later and in Paloro 19 days later in 1938 (Fig. 3) and 36 days later in 1940 (Fig. 4).

This method may have no advantage over that of adequate random sampling in determining the time when splitting occurs when enough trees are available to furnish samples of adequate size without disturbing their crop equilibrium. Adequate random sampling of fruit becomes more difficult as the season progresses and visual differences become more marked. The procedure also assumes that splitting will be reflected in the cross and suture diameter measurements at about the time that it occurs. Such an assumption may not be valid since it is possible that the time of splitting as shown by histological examination may differ from that shown by the external measurements. Whether histological examination would indicate more accurately when splitting occurs than the procedure described here or that of random sampling would seem to depend upon such factors as the mechanism causing splitting and whether histological criteria would be available to demonstrate its occurrence. It may be that the mechanism of splitting is such that it takes place over a short period and any method of determining this time would show the same results.

The chief value of the method would seem to be in an attempt to evaluate the time of splitting in relation to its causes. The behavior of individual fruits may be considered in relation to that of the population in which they occur. The initiation of splitting of different varieties may be studied in relation to the characteristics of their growth curves and likewise the variations that may exist within a variety. These data show that splitting may begin as soon as about seven days after the pit has begun to harden (Fig. 5) or may not begin

until as long as 36 days after it has begun to harden (Fig. 4). Rather large variations may exist within a variety, in 1938 splitting began in the Paloro about 19 days after pit hardening (Fig. 3) but in 1940 it was about 36 days (Fig. 4).

Summary

A method is described for estimating the time when splitting occurs by comparing the seasonal curves of the S/C ratio of split and unsplit fruit calculated from the average size of the two diameters. The time when the curves rapidly diverge indicates when splitting begins.

Fruits that will have split-pits are larger than those that will not have them in both the suture and cross diameters and the ratio of the suture to the cross diameter is smaller early in the season, previous to pit hardening, but the differences are not great.

At maturity the suture diameter of split-pit fruits is generally less and the cross-diameter is greater than that of non-split fruits.

The differential growth of the diameters is especially favorable for a comparison of the ratio of suture to cross diameter for split and non-split fruit.

The seasonal changes of the S/C ratio of unsplit fruits shows three general periods; the first in which the value decreases, the second in which the value remains relatively constant or increases and the third in which it decreases again.

The seasonal changes of the S/C ratio of split-pit fruits differs sharply from that of non-split ones; a first phase similar to or identical with that of non-split fruits occurs; a second phase similar to that of non-split fruits may be present or it may be lacking. When present it is much shorter than in non-split fruits. The last phase is characterized by an abrupt steepening of the curve downward. This abrupt steepening of the curve downward is considered to mark the initiation of splitting.

The chief value of this method of estimation of the time when splitting occurs seems to be an attempt to evaluate the time of splitting in relation to the factors producing it.

The incidence of splitting may vary in different varieties in reference to the time when pit hardening begins and the same variety may show differences in time of splitting.

In all the cases investigated splitting has occurred after the pit has begun to harden.

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Climate in Relation to Deciduous Fruit Production in California. I. Effect of the Warm Winter of 1940–41 on Peach and Nectarine Varieties in Northern California

By REID M. BROOKS and GUY L. PHILP, *University of California, Davis, Calif.*

THE relation between variations in climate and the amount of flower bud drop on deciduous fruit trees has had the attention of California fruit growers for many years. Peach and nectarine trees in the Brentwood, Sutter Basin, and Davis areas of California were dropping an unusually large number of flower buds by the latter part of January, 1941. In the months preceding this observation there had been fewer hours at or below 45 degrees F than during the same period in any of the preceding 11 years for which orchard temperature records were available.

A detailed study was made of the effect of climate on the fruit production of 280 peach and 58 nectarine varieties after relatively high winter temperatures.

MATERIALS AND METHODS

Observations for each variety recorded herein were made on at least two trees; with some having been made on four or six trees — all in the University of California varietal collections at Davis. These trees varied from 4 to 15 years in age, with the latter predominating.

The trees were observed three different times: (a) February 19, 20, and 21 when the flower buds were swelling; (b) March 14 and 15 when most varieties were in full bloom; and (c) April 5 and 7 when the petals of some varieties and jackets (floral tubes) were falling. To determine the amount of bud drop for each survey, an estimation was made of the total flower bud complement on each tree. Leaf buds were not affected.

To obviate as much as possible the personal factor, each survey on each date was independent of the one preceding; each author independently observed all varieties before data were compared and the final class for a variety was selected.

RESULTS

The accumulated hours at or below 45 degrees F at Davis, California, for the five months September to January, inclusive, are given in Table I for the 12-year period 1929–30 to 1940–41. According to these records, the winter under consideration was the warmest of the past 12 seasons exceeding by almost 300 hours the next two warm winters, 1934–35 with 960 accumulated cold hours, and 1939–40 with 961 hours.

The results are shown in Tables II and III, with the varieties arranged alphabetically in their respective classes, depending upon the amount of bud drop observed. Four classes were made as follows:

Class I:—Trees showed *no* dropping of flower buds, but at full

TABLE I—HOURS AT OR BELOW 45 DEGREES F FOR FIVE MONTHS PRECEDING FLOWERING OF PEACHES AND NECTARINES FOR 1929 TO 1941, DAVIS, CALIFORNIA

Season	September	October	November	December	January	Total
1929-30.....	40	73	293	298	423	1127
1930-31.....	0	88	233	401	371	1093
1931-32.....	28	90	268	388	425	1199
1932-33.....	0	67	134	582	560	1343
1933-34.....	16	49	281	477	427	1250
1934-35.....	14	25	127	349	445	960
1935-36.....	20	108	364	395	279	1166
1936-37.....	8	50	307	446	656	1467
1937-38.....	10	26	160	395	537*	1128
1938-39.....	3	82	297	391	423	1196
1939-40....	11	85	281	335	249	961
1940-41....	0	51	222	213	191	677

*Records for January 4-17, 1938 were supplied from a temperature station (Winters, 15 miles from Davis), where the fall and winter temperatures are similar to those at Davis.

bloom had a full complement of flowers — as many as the tree could produce under optimum conditions. Ordinarily such a bloom would result in a tremendous crop. A tree was placed in this class if it had 85 to 100 per cent of its full number of flower buds, or flowers, or an optimum of young fruits after fertilization.

Class II:—Trees showed a *slight* drop of flower buds but had a sufficient number left to produce a full crop of fruit. If a tree had 50 to 85 per cent of its flower buds, flowers, or expected number of young fruits, the variety was placed here.

Class III:—Trees showed a *moderate* drop of flower buds, in which case it might be doubtful whether they could produce a full crop of fruit. A variety was placed here if 15 to 50 per cent of its flower buds or flowers were still present on the tree.

Class IV:—Trees showed a *heavy* drop of flower buds, zero up to 15 per cent of the possible flower buds being left on the tree. No commercial crop of fruit could be produced.

For the past two years, the flower buds on several varieties of peaches, apricots, and plums have been counted to determine the actual percentage of bud drop. These counts were made weekly for a 10-week period ending shortly after full bloom of the particular variety. This gave a background for estimation of the percentage of flower buds on a particular tree. When variation in the classification of a variety occurred, outstanding cases are so indicated by the use of a dagger (†) in Tables II and III.

DISCUSSION

Chandler and his coworkers (1) have indicated that Mayflower, among all the many peach and nectarine varieties studied, required the greatest amount of chilling to break its rest, it being closely followed by Alexander and Briggs. As noted in Table II, these and many other varieties, for example, Florence, Greensboro, Hales Early, June Elberta, Late Crawford, Libbee Cling, Mayflower, Ontario, Red Bird, South Haven, Triumph, and Tuscan, are in class IV (that of heavy bud drop). These varieties will produce little or no fruit in 1941. Among the nectarines (Table III) Boston, Lippiatts Late Orange, John Rivers, Lord Napier, and Quetta also show a serious bud drop.

TABLE II—Peach Varieties Ranked According to Amount of Bud Drop (Davis, California, 1941)

	Class I (No Bud Drop)	
Angel	Florida Gem	Pallas
Australian Saucer	Gibbons October	Peento
Bokhara	Honey	Pomona†
Bolivian Cling (P.I. 36126)	Leona†	Smith
Chilow	Luken	Vivid Globe
Dorothy	Lukens Honey	Waldo
Engle	Osprey Improved (P.I. 43134)	Winter Freestone
	Class II (Slight Bud Drop)	
Annabel	Helen	Pullars Cling (P.I. 68352)
Banner	Honey Cling	Radiance
Barbara	Ideal (P.I. 43127)†	Raisin Cling†
Belle	Ijam Tuscan	Rio Oso Gem†
Best June	Japan Dwarf	Red Muir
Bitterless Elberta	Jean Tuscan	Rosebud
Blood Cling*†	J. H. Hale†	Sabichi Winter
Blood Leaf Cling	July Elberta	Salwey
Captain Ede	Johnson	Salwey Type
Crosby	Klondike	Sea Eagle
Currie Free	La Grange	Selma
Dahling Cling	Late Champion (P.I. 43129)	Shamrock
Delicious	Late Elberta	Shalil (P.I. 63851)
Early Elberta	Lemon Cling	Shippers Cling P.I. 43136)
Early Imperial	Lemon Free	Smith Indian
Elberta	Levy	P.I. 43289
Estella	Liberty	P.I. 55835
Everbearing	Lovell	P.I. 55836
Fay Elberta	Mammoth Heath†	P.I. 55888
Frank Yellow Cling	Marigold	P.I. 61302
Frederica	Massasoit	Sunbeam
Gaume	Millers Late	Stump
George Late†	Morris White	Taylor
Goin	Motions Cling (P.I. 43132)	Thurber
Golden Chinese	Mowrys Strawberry Cling	UC Station Seedling 28140
Golden Jubilee	Munford	Vainqueur
Golden Queen (P.I. 68353)	Perfection	Vedette†
Goodmans Choice (P.I. 55549)	P.I. 43289	Vanemmon
Goodmans Choice (P.I. 68354)	P.I. 55835	Victor†
Haights Late Free	P.I. 55836	Washington
Harris	P.I. 55888	Wilma†
Harris Yellow Cling	P.I. 61302	Yellow Hiley
Heath Cling	Pinkham	
Halford No. 2†	Placer Cling	
Halford No. 3	Prince of Wales	
	Class III (Moderate Bud Drop)	
A-1 (P.I. 43124)	Hardy Elberta	P.I. 55564
Albright Cling	Halford No. 1	P.I. 55813
Alton	Hobson	Radiant
Ames No. 1	Illinois	Red Bird ×Quetta Seedling
Ames No. 2	J. M. Mack	Rochester
Babcock	Krummel	Sellers Cling
Bell October	Lady Palmerston	Shalil (P.I. 36485)
Bilyeu	Lippiatt (P.I. 43130)	Shalil (P.I. 63850)
Blood Cling†	Mary	Shalil (P.I. 63852)
Blood Free	Minnie Stanford	Sims Cling
Blood Peach (P.I. 48508)	Mississippi	Stearns
Buckhorn	Monte Vista Cling	Stinsons
Buttercup	Mother	St. John
Cameo	Mothers Favorite	Tena
Carman	Muir	Thurmond Cling
Cumberland	Newhall	Tribbles Cling
Cotogna di Siena	New Jersey	Tribbles Free
Crimson Cling	Niagara	Tribbles Pride
Cuban Nut	Nichols Orange Cling†	UC Station Seedling 2854
Days Late Cling	October Beauty	UC Station Seedling 34775
Eclipse	Octoberta	Up-to-date (P.I. 43137)
Elberta Cling	Oldmixon Free	Vaughan
Eureka	Oriole	Valiant
Globe	Paloro	Viceroy
Gold Dust	Paragon (P.I. 43135)	Walton
Golden Sweet Cling	Peak	West Late Free
Grosse Mignonne	Phillips Cling†	Wilbur
Hale Cling	Picquet Late	Wiley Cling
		Worth

†This variety is borderline between this class and the one with the greater bud drop.
*A variable type rather than a definite variety.

TABLE II—(*concluded*)

	Class IV (Heavy Bud Drop)	
Admiral Dewey	Hales Early	P.I. 35201
Alexander	Home Freestone	P.I. 41395
Alpha Tuscan	J. H. Keith Early May	P.I. 43291
Amsden	June Elberta	P.I. 55563
Arp	Katie	Pratt Lowe
Bresquilla (P.I. 43569)	Lady Lindsey	Red Bird
Briggs	Late Crawford	Runyons Orange Cling
Brooks Beauty	Late Tuscan	Sharpe
Carota	Leader	Sherman Cling
Champion	Libbee Cling	Sneed
Duchess of Cornwall	Mayflower	South Haven
Earliest	McDevitts Cling	Stark Summer Heath
Early Charlotte	McKevitt	Strawberry*
Early Japanese	Ming Tomb	Strawberry Cling
Early Rose	Morellone	Strawberry Free
Early Wheeler	Mountain Rose	Susquehanna
El Solyo Seedling	National	Sutter Creek (P.I. 36125)
Feicheng (P.I. 38178)	Newcastle Tuscan	Sutter Seedling
Fitzgerald	Noble Red	Tardio Encarnado (P.I. 43568)
Florence	October Indian	Togo
Foster	Oklahoma Beauty	Tossetti Late Free
Franks Cling	Oklahoma Queen	Triumph
George IV	Ontario	Tuscan (Tuskena)
Gilla Tardiva di Milano	Opulent	Veteran
Gillingham	Orange Cling	Wards Late
Greensboro	Peregrine	Yellow Swan

†This variety is borderline between this class and the one with the greater bud drop.
*A variable type rather than a definite variety.

As Tables II and III illustrate, most commercial peach and nectarine varieties fall into classes II and III (slight and moderate bud drop, respectively). For all the peach and nectarine varieties in class III, for example, Babcock, Carman, Muir, Paloro, Phillips Cling, Rochester, St. John, Valiant, Viceroy, fruit production is seriously reduced. This is not true of most varieties in class II, for example, Currie Free, Elberta, Fay Elberta, Frederica, Gaume, July Elberta, Levy, Lovell, Salwey, and Sunbeam.

The peaches and nectarines showing little or no bud drop are mainly

TABLE III—NECTARINE VARIETIES RANKED ACCORDING TO AMOUNT OF BUD DROP (DAVIS, CALIFORNIA, 1941)

	Class I (No Bud Drop)	
Davis	Red Cling	Wilkinson
Dixie		
	Class II (Slight Bud Drop)	
Gold Mine	Muirs Seedling	P.I. 65976
Gowert†	New Boy	P.I. 65978
Griffith	New White	Stanwick
Hardwicke	Nigh	Stanwick Elrudge
J. C. Weese	Pineapple (P.I. 74011)	Surecrop
Mexican	P.I. 65973	Victoria
	P.I. 65975	
	Class III (Moderate Bud Drop)	
Advance†	Early Rivers	Ozark
Ansenne	Gold Seedling	P.I. 65978
Burbank Blood	Humboldt	Red Roman
Downton	Kathryn	Spanish
Dryden	Nettarino Gilla d'Padova	Spencer†
Early Newington	Newton	Violet
	Class IV (Heavy Bud Drop)	
Boston	Lord Napier	P.I. 65974
Cardinal	Milton	P.I. 68178
Fishers Yellow	P.I. 26503	Quetta
Gaylord	P.I. 29227	Smith
John Rivers	P.I. 30648	Togatch Moneck
Lippiatts Late Orange		Traveller

†This variety is borderline between this class and the one with the greater bud drop.

Honey or Peento types, which have little or no commercial value. These, however, are useful for breeding, especially in areas more seriously affected with delayed foliation than those in northern California.

Lammerts (2) has suggested using St. Helena (a variety not growing in the Davis collection) as a biological indicator of the behavior of commercial varieties for southern California. Judging from his observation of St. Helena, its growth response is a reliable indication of the amount of bud drop to be expected with commercial varieties.

About one-half of the varieties had completed their bud drop at the time of the first survey (February 20); thus the three surveys coincide. Some examples are Alexander, Briggs, Florence, Gaume, Greensboro, Hales Early, Hauss, Honey, Johnson, Late Elberta, Libbee Cling, Mayflower, Muir, Oriole, Peento, Red Bird, Salwey, Strawberry Free, Boston, Early Rivers, Humboldt, New Boy, Spanish, and Traveller.

A few varieties tended to drop additional buds between February 20 (flower buds beginning to swell) and March 15 (full bloom); examples are Alton, Early Crawford, June Elberta, Late Tuscan, Marigold, Wilma, and Yellow Hiley. The last survey (April 5 to 7) invariably agreed well with the preceding observation; if any change was apparent, it was always to a more severe drop than previously noted. In most instances, this new observation did not change a variety to the next class but only emphasized the class in which it had earlier been placed.

Hutchins, cited by Weinberger (3), has stated for Georgia conditions that 1000 accumulated hours of 45 degrees F or below are sufficient to break the rest period for most varieties of peaches. Table I indicates that at Davis, California, much less accumulated cold was recorded in 1940–41 than in the previous 12 seasons. The observations presented herein indicate that bud drop occurred rather early in the season, probably before the first of February for most varieties. But drop had already been noticed in several widely scattered fruit-growing sections by the end of January. Thus the climatic factor or factors that evidently enter into a tree's dropping of its flower buds had been operating during the 1941 season by January 10 or even earlier.

Summary

Two hundred and eighty peach and 58 nectarine varieties were observed in the spring of 1941 for their susceptibility to dropping their flower buds after the warm winter of 1940–41. These varieties were placed in four classes depending upon the amount of bud drop observed. The results are given in tabular form.

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A Foliarmetric Gauge

By E. M. MEADER, *U. S. Department of Agriculture,* and
M. A. BLAKE, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

CHARACTERISTIC varietal differences in foliage of the peach have been suggested by Sefick and Blake (4) for a classification of varieties to aid in their identification. To describe readily observable differences in the width-to-length ratio, apex and base angles of leaves of varieties, they measured the length and maximum width of leaves upon a scale drawn to 0.1 inch horizontally and vertically on cardboard and the angles with a special protractor.

The authors found it difficult and tedious to make accurate measurements of the angles of a leaf at fixed distances (1 inch and 0.5 inch) along the midrib from the ends of the leaf blade with a protractor. As a result, the gauge illustrated in Fig. 1 has been devised to facilitate rapid measurements of leaves in peach varietal studies (2, 3) carried on at the New Jersey Agricultural Experiment Station. By use of this measuring device, it is possible to describe with mathematical precision the width-to-length ratio, in per cent and apex and base angles of the leaf blade in degrees. Since the principles of measurement embodied in the peach foliarmetric gauge may be of general plant taxonomic interest, a detailed description of its construction and use are presented herein.

DIRECTIONS FOR USE AND CONSTRUCTION OF FOLIARMETRIC GAUGE

The peach foliarmetric gauge has four scales. The top one (see Fig. 1) is for measurement of the apex angle of a leaf at 1-inch distance along its midrib. The bottom scale is for measurement of the base angle of the leaf at 0.5-inch distance. The two remaining scales are for measurement of the length and maximum width of the leaf by placing it in a single position upon the central portion of the gauge.

Apex-Angle Measurement:—To measure the apex angle of a leaf, its tip is so placed that it just touches line AB with the midrib being maintained parallel to AC (see Fig. 2). The margin of the leaf at its left hand edge should just touch the point at which lines AC and CD intersect. Then at whatever point the margin of the leaf at its right hand edge intersects CD, the apex angle of the leaf can be read directly from the numerical scale in degrees. If the margin happens to fall between the gradations of the scale, the angle can be read to the proper degree by interpolation. Each gradation equals 2 degrees. For example, the apex angle of the leaf illustrated in Fig. 2 equals 31 degrees.

Construction of Apex-Angle Scale:—Lines AB and CD (Fig. 1) should be parallel and spaced 1 inch apart. Their left hand ends should be connected by a line, AC. This scale is based upon a trigonometric ratio, the tangent of an angle, in similar right triangles which have one side in common. For example, (Fig. 2) at the tip of a leaf, two angles are formed by the margin and the midrib. Their sum is the apex angle which, for all practical purposes, is bisected by the midrib. The line

from margin to margin of the leaf drawn perpendicular to the midrib at 1-inch distance from the apex tip forms two similar right triangles. The 1-inch distance along the midrib is common to the two triangles. Then, in each of these right triangles, by formula:

$$\text{tangent leaf-tip angle made by margin and midrib} = \frac{\text{perpendicular to midrib from margin}}{\text{distance along midrib from leaf tip}}.$$

Since the distance from margin to margin of the leaf measured

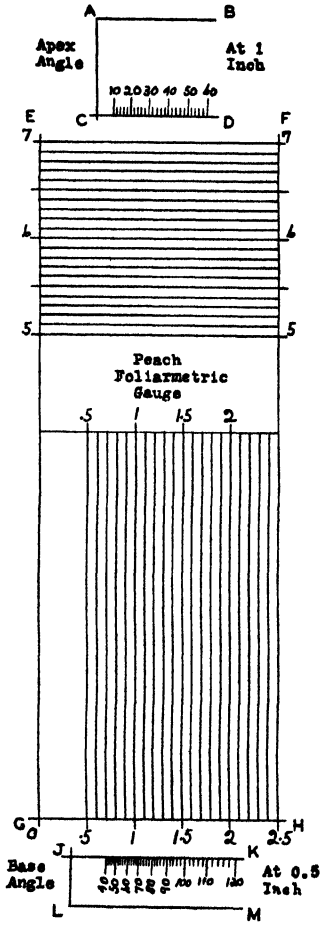

FIG. 1. Peach foliarmetric gauge.

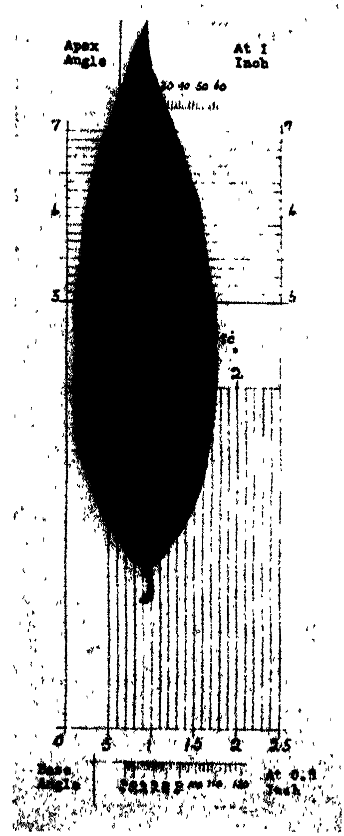

FIG. 2. Leaf in proper position for measurement of its apex angle.

directly upon the gauge is converted by the numerical scale into degrees equivalent to the apex angle, it is this distance that must be known for each apex angle in order to construct the scale. The distance from margin to margin of the leaf is the sum of the two perpendiculars to the midrib from the leaf margin. The length of the perpendicular may be found directly by reference to a table of natural tangents and

the following formula: Perpendicular to midrib from margin = distance along midrib from leaf tip (1 inch) × tangent leaf-tip angle made by margin and midrib. To find the distance from margin to margin of the leaf for any particular apex angle when measured at 1-inch distance along the midrib, look up in a table the natural tangent of one half this angle, and multiply the value by 2.

For instance, for a leaf with a 30-degree apex angle, the tangent of 15 degrees is 0.2679, multiplied by 2 equals 0.5358 inch. This is the distance from margin to margin of this leaf at 1-inch distance along the midrib from the leaf tip. The corresponding distances from leaf margin to leaf margin for each of the apex angles needed upon the scale should be found. These distances should be determined on line CD (Fig. 1) starting from its point of intersection with AC to give the points equivalent to each apex angle lettered upon the numerical scale. The range of the numerical scale should be adequate for any apex angle apt to be encountered in the foliage of the species and varieties to be studied. A range of 10 to 60 degrees was adequate for apex angles of peach leaves.

The distance between any two successive points located upon CD can be found by subtraction of the values determined for the corresponding distances from margin to margin of two leaves having apex angles that differ by 2 degrees. That is, the distance between the points equivalent to 10 and 12 degrees is 0.0352 inch; and at the other end of the numerical scale, the distance between the points equivalent to 58 and 60 degrees is 0.0462 inch.

A scale with gradations equivalent to 2 degrees is easier to read to a degree by interpolation than one which has lines closely spaced so that each gradation equals 1 degree.

For rapid reading of the scale, short vertical lines drawn through the points determined upon line CD should vary in length similar to lines upon a common ruler.

Measurements of Length and Width:—To measure the length and maximum width of a leaf, the point of juncture of its petiole and the base of its blade is placed upon line GH and the margin at the left hand edge of the leaf is so placed that it just touches EG with the midrib being maintained parallel to this line (also see Fig. 3). The length and maximum width are then read from the appropriate numerical scales.

Measurements can be made to the nearest 0.05 inch by interpolation. Since only leaves 5 to 7 inches long were being measured, the numerical scales were adapted to leaves of this size. Normal 5- to 7-inch peach leaves are always wider than .5 inch. The leaf shown in Fig. 3 is 6.4 inches long and 1.65 inches wide at its point of maximum width.

Construction of Portion of Gauge for Length and Width Measurements:—Little explanation of the construction of this portion of the gauge seems necessary since this can be readily observed from Fig. 1. All horizontal lines are parallel, all vertical lines are parallel, and both series of lines are spaced 0.1 inch apart.

The vertical lines should be made long enough to extend above the point of maximum width of any leaf when its base is placed upon the

zero horizontal line, GH. The scales should be lettered with numerals to correspond to the actual distances measured in inches.

Measurement of Base Angles:—To measure the base angle of a leaf, the point of union of its petiole and margin is so placed that it just touches line LM (also see Fig. 4). The margin at the left hand edge of the leaf should just touch the point of intersection of lines JK and JL. For leaves with their margin and petiole joining obliquely, the

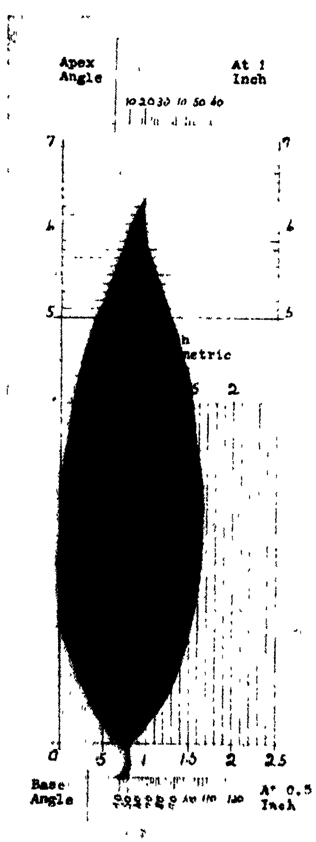

FIG. 3. Leaf in proper position for measurement of its length and maximum width.

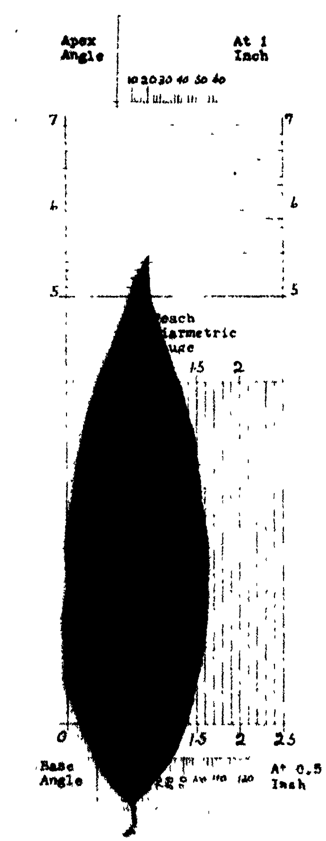

FIG. 4. Leaf in proper position for measurement of its base angle.

lowermost point of union should be consistently chosen. For accurate measurements, the midrib of the leaf must be kept parallel to JL.

Then at whatever point the margin of the leaf at its right hand edge intersects JK, the base angle can be read from the numerical scale in degrees. As in the apex scale, the angle can be read to the proper degree by interpolation; each gradation being equivalent to 2 degrees.

For example, the leaf shown in Fig. 4 has a base angle equal to 81 degrees.

Construction of Base-Angle Scale:—Since the principle of construction of this portion of the gauge is identical to that for measurement of apex angles, the formula already stated may be revised as follows: Perpendicular to midrib from margin = distance along midrib from point of union of leaf margin and petiole (0.5 inch) × tangent leaf-base angle made by margin and midrib. The length of the perpendicular multiplied by two is equivalent to the distance from margin to margin of the leaf. This distance must be known for each base angle in order to locate upon line JK, points which are the equivalents of the angles lettered upon the numerical scale.

For example, for a leaf with a 70-degree base angle the tangent of 35 degrees is 0.7002, multiplied by 0.5 = 0.3501 inch for the length of the perpendicular. This must be multiplied by 2 to give 0.7002 inch for the distance from leaf margin to leaf margin. Thus, the tangent of one half the base angle and the distance from margin to margin of the leaf at a point 0.5-inch distance along the midrib are equivalent. Therefore, to find the distance from the point of intersection of lines JK and JL to locate upon JK a point equivalent to a certain base angle, the natural tangent of one half this base angle can be read directly from a table and expressed as a decimal of an inch.

With the exception that the two parallel lines JK and LM are spaced 0.5 inch apart, construction of this portion of the gauge is similar to the description given for apex angles. The numerical scale lettered from 40 to 120 degrees was adequate for measurement of the base angles of peach leaves.

CONSTRUCTION MATERIALS FOR FOLIARMETRIC GAUGE

The material upon which the scales for measurements are inscribed should be considered from the following points: (a) readability, (b) durability, (c) possibility of duplication of the original gauge, and (d) cost of construction from the material chosen.

Metals:—Sheet brass fastened to a wooden base and 3/16-inch plate brass were found satisfactory materials from the standpoints of readability and durability. Highly polished brass gives a glare that makes reading of the scales difficult. If brass is allowed to tarnish until it has a dull appearance and is then covered with a transparent lacquer, the gauge may be read easily. Further tarnishing by contact with sulphur spray residue upon the leaves used will also be prevented. Engraving of the scales upon brass is a tedious task and costly. Duplication of the original scales is impossible as each gauge must be engraved separately when made of metal. Similar objections may be made to other metals which might be used.

Photographic Paper:—Photographic sensitized paper was the most satisfactory material found for use when all points are considered. The foliarmetric gauge was first inscribed with accuracy to the nearest .001 inch upon a hard surface drawing paper with pen and black India ink. A photograph of the drawing was made with care being taken to have the dimensions of the image upon the ground glass of the camera

correspond exactly with those of the drawing.

As many contact prints of the original drawing can be made from the negative upon a good quality sensitized paper as one may desire. The scales upon glossy prints are easily read. Such a print is durable after it has been cemented to cardboard and its surface protected with a transparent material.

Regardless of the poorer durability of such prints than metals, any number of reproductions of the original foliarmetric gauge can be made economically from the master negative.

Adaption to Systematic Studies of Other Plants

The principles of measurement embodied in the peach foliarmetric gauge can be applied to the foliage of any plants whose leaves are simple and entire.

Adaptation to the Blueberry:—A foliarmetric gauge based upon these methods of measurement has been constructed by Clark (1) for use in varietal studies of the blueberry. Both apex and base angles of the leaves of varieties of *Vaccinium corymbosum* are measured at 0.5-inch distance along the midrib from the ends of the leaf blade. The metric system is used for length and width measurements.

The photographic method for reproduction of the foliarmetric gauge was suggested by Professor J. H. Clark of the New Jersey Agricultural Experiment Station to whom the authors are indebted for this contribution. A limited number of foliarmetric gauges adapted to the peach and blueberry can be secured at cost from the New Jersey Agricultural Experiment Station.

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Some Results of Acidity and Catechol Tannin Studies of Peach Fruits[1]

By M. A. Blake and O. W. Davidson, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

THE acid and catechol tannin contents of peach fruits are important both from the standpoint of consumers of the fresh fruit and from that of the canners and processors of the fruit. The fact is becoming more widely appreciated by physicians and others that some persons cannot consume, without some discomfort, fruits which are too high in acidity.

The senior author and others of his staff who annually sample the ripe fruits of a large number of peach varieties and seedlings, have noted for many years that some are so acid as to make it necessary to take a neutralizing agent at the end of a day of testing.

It is a well-established fact that a fruit relatively high in acid may taste sweet if it is also high in sugar. On the other hand, a peach low in sugar may taste sweet if it is also low in acid. Persons sensitive to acidity can, however, detect the difference. The addition of sugar does not prevent the detection of a strongly acid fruit.

When peach fruits are allowed to ripen on the tree the acidity gradually decreases from the green to the soft-ripe stage as previously reported (1). When the fruits are picked at a green-ripe stage and ripened off the tree, however, the acidity decreases very little.

Catechol Tannin Content in Relation to Edible Quality:—When ripe peaches, high in catechol tannin, are sliced and exposed to the air the flesh quickly discolors to unattractive brownish shades. The flesh of such fruits also discolors quickly when thawed after being frozen. Among the large collection of peaches at New Brunswick there are varieties such as Chinese Blood (P.I. 36717) the fruits of which are so high in tannin that they are relatively unpalatable. Varieties which are medium to high in tannin under the most favorable environmental conditions become high in tannin when grown in an environment which results in an exceptionally high accumulation of carbohydrates. J. H. Hale fruits, for example, in some districts of the country are so high in tannin that they are very astringent and inferior in edible quality. Moreover, peach fruits produced by trees girdled to such an extent that the fruits are abnormally large or ripen prematurely are exceptionally astringent for the particular variety.

It has been observed that when peach fruits are exceptionally high in both acidity and tannin they are unpalatable to one sensitive to acidity.

During the season of 1940, determinations of pH and titratable acidity were made on near-soft-ripe fruits of a total of 1899 varieties, types, and seedling peaches at New Brunswick.

Acidity and Tannin Determinations:—Slices of peach flesh were reduced to a pulp in a food grinder and then strained through a piece

[1]Journal Series Paper of the New Jersey Agricultural Experiment Station, Division of Horticulture.

of longcloth. Ten milliliter samples of juice prepared in this manner were titrated with N/10 NaOH until a deep red color was obtained with phenolphthalein. For this purpose, 1 milliliter of a 1 per cent solution of phenolphthalein of 86 per cent alcohol was used. The pH value of the extracted juice was obtained by means of a glass electrode.

Rapid and reasonably accurate estimations of the tannin content of peach juice were obtained by placing a 4 milliliter sample of juice in a 13 by 100 millimeter test tube and adding 3 drops of a 6 per cent solution of $FeCl_3$. The latter was distributed slightly through the upper portion of the juice by tapping the tube. Catechol tannins react with ferric salts and produce black colorations. The shades of black in the peach juice vary with the quantity of tannins present and with the color of the juice. In general, brown-black to blue-black colors are formed. After standing ½ hour, the tannin content of the juice was estimated according to the color and thickness of the discolored layer formed at the top of the tube. This layer was absent in samples of juice containing no tannins. On the other hand, juices extremely high in tannins produced brown-black or blue-black layers 5 to 10 millimeters in thickness.

This colorimetric method was standardized against the method of Loewenthal and Proctor (2), and the values obtained by the former were expressed comparatively from 0 to 100 in units of 5. These values, when multiplied by the factor, 0.00025 gram, represent the amount of tannin (as gallotannic acid) found in 10 milliliter samples of peach juice by the Loewenthal-Proctor method.

Classification of Varieties According to Relative Acidity

In order to evaluate varieties and the progeny of crosses according to relative degree of acidity, three groups or classes were set up as follows:

1. Very acid: fruits with a pH of 3.79 or less.
2. Medium acid: fruits with a pH of 3.80 to 4.00.
3. Low acid: fruits with a pH of 4.01 and above.

Since the ripening period was unusually cool, and dull weather occurred at certain intervals during 1940, the fruits of some varieties may have been more acid than usual. Fruits with a pH of less than 3.70 and a titratable acidity above 10 were very acid to the reaction of those persons who sampled them, while peaches which tested above pH 4.00 were only mildly acid to the taste.

Data from representative varieties of each class are given in Table I.

Classification of Varieties upon Basis of Content of Catechol Tannin

For purposes of classification and evaluation, five groups or classes have been set up on the basis of the degree of astringency as follows:

1. Very low with rating of 0 to 10.
2. Low with rating of 15 to 25.
3. Medium with rating of 30 to 50.
4. High with rating of 55 to 75.
5. Very high with rating of 80 to 100.

TABLE I—VARIETIES OF PEACH CLASSIFIED UPON BASIS OF RELATIVE ACIDITY, NEW BRUNSWICK, N. J.

Varieties	pH	Titratable Acidity
1. *Very Acid*		
Duke of York	3.54	10.22
Fair's Beauty	3.55	13.52
Fertile Hale	3.59	10.29
J. H. Hale	3.61	10.71
Mamie Ross	3.68	10.68
Greensboro	3.71	9.68
2. *Medium Acid*		
Kalhaven	3.80	8.80
Rosebud	3.89	9.40
Buttercup	3.91	8.10
Engle's Mammoth	3.92	9.60
Chili	3.99	7.50
Hiley	4.00	9.78
3. *Low Acid*		
Chair's Choice	4.01	9.48
Mayflower	4.15	6.78
Goldeneast	4.18	6.32
Vedette	4.27	8.20
Admirable Juane	4.40	6.22
Eclipse	4.80	5.13

Fruits in classes 4 and 5 were astringent enough to be somewhat unpleasant in effect to the persons sampling the fresh ripe fruits in the field during 1940.

Fruits which were high in both acidity and tannin were especially unpalatable to samplers. The fruit of General Lee Cling was a good example of this combination, since the pH was 3.71, the titratable acidity 12.64, and the catechol tannin 90.

TABLE II—VARIETIES OF PEACH CLASSIFIED UPON BASIS OF RELATIVE TANNIN CONTENT, NEW BRUNSWICK, N. J.

Varieties	Tannin
1. *Very Low*	
Sunbeam	0–5
Goldfinch	5
Chili	10
Fair's Beauty	10
Kathryn	10
2. *Low*	
Massasoit	15
Carman	20
Early Crawford	20
Late Crawford	20
Veteran	20
3. *Medium*	
Elberta	35
Lizzie	35
Chinese Cling	40
Iron Mountain	40
Mayflower	45
4. *High*	
Burbank's Giant Freestone	65
Red Magdalen	65
Mikado	70
Primrose	70
Up-to-Date	70
5. *Very High*	
Illinois	80
Mitchelson	80
General Lee	90
Golden Giant Cling	90
Chinese Blood	100

Examples of varieties representative of the five classes of astringency as determined in 1940 are listed in Table II. Varieties which are near the border line of any class may vary between two classes from season to season.

Observations on the Inheritance of Acid and Tannin Characteristics

The crossing of two varieties with very acid fruits has resulted in progeny a high proportion of which bear acid peaches. When one parent is relatively high in acid and the other relatively low, the degree of acidity of the progeny apparently varies according to the varietal fruit type which dominates in the cross. When two varieties very low in tannin have been crossed at New Brunswick a considerable proportion of the progeny has been low in tannin. When one parent of a cross was low in tannin and the other medium to high, very few, if any, of the progeny yielded fruits which were very low in tannin. When both parents have been high in tannin a large proportion of the progeny yielded fruits which were high in tannin.

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An Evaluation of Peach and Nectarine Varieties in Terms of Winter Chilling Requirements and Breeding Possibilities

By W. E. Lammerts, *University of California, Los Angeles, Calif.*

THE marked delay in leafing and flowering of most peaches and nectarines, followed by reduction in quality and quantity of fruit, so often observed in coastal southern California following mild winters is due as shown by Weldon (1) to insufficient chilling. Although a general grouping in terms of chilling requirements has been made by Chandler *et al.* (2) a more exact evaluation is needed for an effective breeding program. In the present study a method of indexing is presented which shows the wide range of varietal reactions to mild winters more clearly than the customary method of giving arbitrary grade numbers. The breeding value of certain varieties and the use of others as climatic indicators is also discussed.

Material and Methods

These studies were made possible through the courtesy of Armstrong Nurseries, Ontario, California, where a varietal collection containing at least two and often six trees of many varieties was available until 1939. Many of the older varieties were then discarded leaving only 23 of the original ones. Some newer introductions observed from 1939 to 1941 are included in Table II. The exact dates recorded for beginning of leafing are somewhat arbitrary especially in seasons following mild winters, but in general indicate that one-eighth to one-quarter of leaf growth had occurred on at least the terminal buds. Lateral buds were, of course, always later in years of insufficient chilling.

Observations

The comparative 40 degrees F temperature hours are given in Table I along with other pertinent data. As shown graphically on the left in Fig. 1, leafing out was practically simultaneous with flowering following the relatively cold winter of 1936–1937. The behavior following the warmer 1937–1938 winter is shown on the right and may be summarized as follows:

TABLE I—Comparative Total of 40 Degrees F Hours, Nights Below 32 Degrees F, 40 Degrees F and Time of First Frosts at Ontario, California From 1936 to 1941

Year	No. 40 Degrees F Hours Nov 2 to Jan 10	No. 40 Degrees F Hours Jan 10 to Mar 1	Total 40 Degrees F Hours	No. Nights Below 32 Degrees F	No. Nights Below 40 Degrees F	Time and Degree of First Frost
1936–37	426	487	913	55	77	Dec. 28–28 degrees
1937–38	176	230	406	8	53	Dec. 23–29 degrees
1938–39	285	362	647	22	69	Nov. 11–13–24 to 26 degrees
1939–40	159	202	361	14	43	Dec. 23–29 degrees
1940–41	256	107	363	4	45	Dec. 14–25 degrees

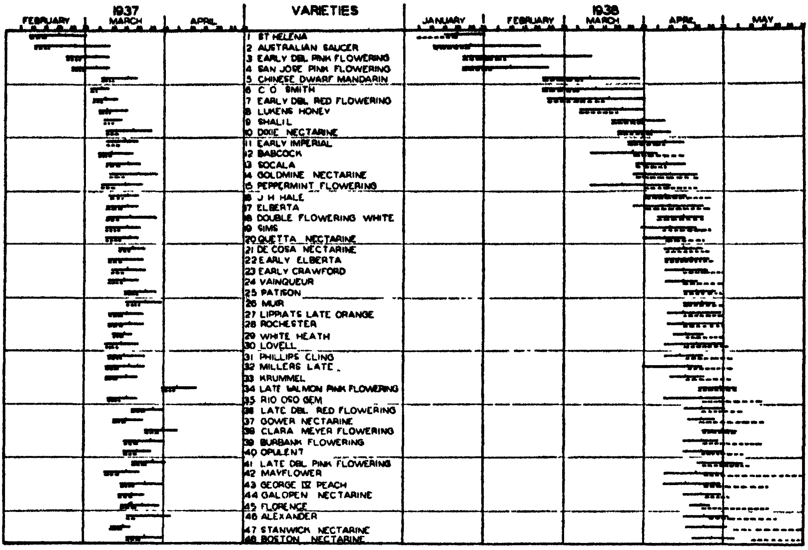

FIG. 1. Peach and nectarine varieties arranged according to order of leafing out following comparatively mild winter of 1938. The solid line and indicated peak represents flowering and dotted line leafing out.

1. Grade 0 and 1 varieties leafed out from 2 weeks to 1 month earlier.
2. Grade 7 and 8 varieties leafed out as much as 66 days later, flowering preceding leafing by 2 to 3 weeks.
3. The interval between the first and last blossom was longer.

Since Lukens Honey is a well known variety of local origin which rarely, if ever, is seriously delayed in foliation, it was selected as a basis of comparison. Over a period of 6 years it varied only 6 days in leafing and flowering (Table II). By using the 1937 behavior as representative of the reaction of varieties to sufficient chilling, the advancing or retarding effect of mild winters may be expressed as minus or plus deviations from the 1937 dates. Lukens Honey is given a base rating each year of 0, indicative of its relative lack of reaction to yearly temperature variation. The results of this method of evaluating varieties are given in Table II under column labeled "1938 Index Numbers". Thus, Boston nectarine leafed out 10 days later than Lukens Honey, or March 16, 1937, as compared to 66 days later or May 11, in 1938. It took 56 days longer to leaf out in 1938 so is given an index number of +56. Of all the varieties studied, it is most adversely affected by mild winters.

Certain discrepancies between the index numbers and arbitrary grades occur which emphasize the greater accuracy of the index system. Thus Late Salmon Pink Flowering evidently has the same chilling requirement as Elberta, though it leafed out later even than Vainqueur in 1938 and accordingly was placed in grade 7. Reference to the 1937 behavior as shown by the index number +23 shows that it is genetically

TABLE II—VARIETIES OF PEACHES AND NECTARINES LISTED IN ORDER OF 1938 INDEX OF CHILLING REQUIREMENT AS DETERMINED BY 1938 BEHAVIOR RELATIVE TO THAT OF 1937 USING LUKENS HONEY AS A CONSTANT BASE (THE GRADE NUMBERS FORMERLY USED ARE ALSO GIVEN, INDEX NUMBERS FOR 1938, 1940, AND 1941 ARE GIVEN FOR VARIETIES OBSERVED)

Variety	Arbitrary Grade Number	Minus and Plus Deviations From Lukens Honey Leafing Out Date		Index Numbers			
		1937	1938	1938	1939	1940	1941
St. Helena seedling*	0	−25	−61	−36	−45	−18	−30
San Jose Pink Flowering	0	− 9	−42	−33	—	—	—
Australian Saucer	0	−23	−54	−31	−38	− 5	−27
Early Double Pink Flowering	0	−11	−42	−31	−32	−19	−22
Chinese Dwarf Mandarin	1	0	−12	−12	−46	−23	−26
C. O. Smith	1	− 4	−12	− 8	− 7	− 1	− 5
Early Double Red Flowering	1	− 3	−10	− 7	− 7	− 8	− 7
Lukens Honey	2+	0=3/6	0=3/6	0=3/6	0=3/11	0=3/7	0=3/6
Shalil (P.I. 63850)	2	+ 1	+12	+11	+ 3	+16	—
Dixie Nectarine	2	+ 2	+14	+12	+10	+22	+12
Early Imperial†	3	+ 2	+18	+16	+ 9	+30	—
Goldmine Nectarine	4	+ 3	+20	+17	+12	+33	+15
Socala†	2−	+ 2	+21	+19	+12	+19	+12
Babcock†	2−	0	+20	+20	+13	+13	+10
Golden Blush	—	+ 2	—	—	+22	+26	—
Late Salmon Pink Flowering	7	+23	+46	+23	—	—	—
Leeton	—	+ 2	—	—	+23	+41	—
J. H. Hale†	4	+ 2	+26	+24	+25	+58	+48
Elberta†	4	+ 2	+26	+24	+20	+59	+43
Peppermint Flowering	4	0	+25	+25	+11	+ 8	—
DeCoosa Nectarine (P.I. 65974)	5	+ 7	+33	+26	—	—	—
White Double Flowering	5	+ 2	+30	+28	—	—	—
Sims†	5	+ 2	+32	+30	+28	+52	—
Early Elberta	5	+ 3	+33	+30	—	—	—
Quetta Nectarine	5	+ 3	+33	+30	—	—	—
Muir	6	+10	+40	+30	—	—	—
Clara Meyer Flowering	7	+17	+47	+30	—	—	—
Pateson	6	+ 9	+40	+31	—	—	—
Late Double Red Flowering	7	+12	+47	+35	—	—	—
Late Double Pink Flowering	7	+12	+48	+36	—	—	—
White Heath	6	+ 5	+41	+36	—	—	—
Early Crawford	6	+ 4	+40	+36	—	—	—
Rochester	6	+ 3	+40	+37	—	—	—
Lippiats Late Orange Nectarine	6	+ 3	+40	+37	+26	+56	—
Vainqueur (P.I. 33219)	6	+ 2	+40	+38	—	+55	—
Opulent	7	+ 9	+47	+38	—	—	—
Phillips Cling†	7	+ 3	+41	+38	—	—	—
George IV	7	+ 8	+47	+39	—	—	—
Burbank Flowering	7	+ 9	+48	+39	—	—	—
Krummel	6	+ 2	+41	+39	—	—	—
Lovell†	6	+ 2	+41	+39	—	—	—
Miller's Late	6	+ 2	+42	+40	—	—	—
Galopin Nectarine (P.I. 65976)	7	+ 7	+47	+40	+18	+51	—
Alexander	7	+10	+50	+40	—	—	—
Gower Nectarine	7	+ 5	+46	+41	—	—	—
Florence	7	+ 3	+47	+44	—	—	—
Rio Oso Gem	7	+ 3	+47	+44	+32	+51	—
Mayflower	7	+ 2	+48	+46	+38	+56	+53
Stanwick Nectarine	8	+ 4	+59	+55	—	—	—
Boston Nectarine	8	+10	+66	+56	+34	+57	—

*Grown from seed of the St. Helena obtained from W. F. Wight of the United States Department of Agriculture, Palo Alto, California.
†Entire orchards of 5 to 20 acres were available for observation.

late flowering. Muir has a lower index number than Lovell though both were given the same grade 6 rating in the spring of 1938 because they leafed out together. The higher yield of fruit on Muir in the summer of 1938 showed that the index number gave a better indication of the ability of the variety to tolerate mild winters. Goldmine and Dixie nectarines as shown by their index numbers are much the best nectar-

ines for southern California, though the yield was cut to only a few fruits per tree in 1938 and 1940. Galopin nectarine in spite of late leafing bore surprisingly well every year, so may be of value in nectarine breeding.

1939 Behavior:—Though January 1939 was warm, February was relatively cool, so Lukens Honey was delayed 5 days in leafing out. Following the heavy frost of November 11 to 13, 1938 (Table I), 647 40 degrees F hours accumulated by March 1, 1939 as compared with only 406 for 1937–1938. Accordingly, chilling requirements were better satisfied, as shown by the lower plus values of index numbers. In 1937–1938 no fall frost occurred, and the Chinese Dwarf Mandarin peach continued growing until early in January when it dropped most of its leaves. St. Helena dropped all except its terminal leaves much earlier. Its lateral buds leafed out January 4, 1938. A certain minimum accumulation of 40 degrees F hours is needed even for varieties such as Chinese Dwarf Mandarin in order to break the rest, so leafing out did not occur in this variety until February 22, 1938. In 1939, however, following the heavy November frosts, growth ceased and most leaves dropped. It then leafed out January 24, 1939 as shown by the index number —46. St. Helena was also earlier.

Evidently mild temperature varieties do not enter the rest period early as varieties such as Elberta, J. H. Hale or Mayflower. These varieties begin dropping their leaves early in the fall after a few cool nights; an indication of their adaptation to cold north temperate zone climates, where active growth in the fall might prove fatal if followed by sudden low temperatures.

1940 Behavior:—In 1939–1940 only 361 40 degrees F hours occurred of which 159 had accumulated by January 6, 1940. No heavy frosts occurred. The terminal shoots of St. Helena and Chinese Dwarf Mandarin continued actively growing all winter. The lateral buds, however, were dormant during the latter part of December and most of January. These varieties were paradoxical in being partially evergreen and delayed in foliation at the same time. The index numbers —18 for St. Helena and —23 for Chinese Dwarf Mandarin refer to the leafing out of the lateral buds. Australian Saucer and Double Flowering Pink were actually delayed in leafing as compared to 1938 and 1939. All other varieties were severely delayed in leafing with the exception of Babcock and Peppermint.

1941 Behavior:—The winter of 1940–1941 was again very mild but slightly cooler than 1939–1940, 363 40 degrees F hours occurring of which 246 accumulated before January 6. Accordingly the lateral buds of St. Helena and Chinese Dwarf Mandarin leafed out earlier than in 1940. In spite of the very cool and humid February and early March weather, the varieties with longer chilling requirement leafed out much later than in 1937. The delay was not as great as in 1940, being more comparable to that observed in 1939.

The adverse effects of insufficient chilling on quality, quantity and time of ripening of the fruit may be summarized as follows:

1. Actual decrease in yield, no crop at all in case of Boston Nectarine and Mayflower.

2. Poor quality of fruit, including such effects as increased bitterness, exudation of gum and split pits.
3. Excessive set on some branches and little or no set on others, particularly noticeable on Sims, and to some extent on Babcock.
4. Delay in time of ripening and resulting competition with early regions in the northern part of the state.

The amount of these types of injury was closely correlated with the size of the positive index numbers in any year and from year to year, except in the case of Muir, Millers' Late and Galopin nectarine. Babcock ordinarily is considered as having a sufficiently low chilling requirement, but is on the borderline from the commercial point of view. In 1938 it began ripening July 17, reached the peak on July 26, and ended August 6. The main crop of J. H. Hale and Elberta from northern districts was thus on the market in competition with it. The same condition obtained to some extent in 1939 and 1940, though it ripened progressively earlier these years.

The occurrence of twin, triple, quadruple and even quintuple fruits is correlated with the size of positive index numbers. Varieties with low chilling requirements do not show this tendency and multiple pistils and fruits were not observed in 1937.

Mayflower ripened May 22 in 1937 only 70 days after flowering. In 1938, due to insufficient chilling it did not begin flowering until April 8 and reached its peak April 20. The few fruits,— large for the variety — ripened June 5 to 10. Their maturity cycle was shortened to 60 days. Vainqueur also has a relatively short maturity cycle.

The following yellow-fleshed peaches may be of value in breeding for varieties of low chilling requirement because of indicated qualities:

1. Socala — little delay in leafing, good crop 1938 to 1940, high quality large freestone, 105 day maturity cycle.
2. Leeton — more delayed in leafing but fair crop, semi-cling, 90-day maturity cycle.
3. Golden Blush — also delayed in leafing but adequate crop very large high quality fruit.

Discussion

By recording the number of hours at 40 degrees F, up to January 6 and observing the behavior of early-leafing types as St. Helena and Chinese Dwarf Mandarin, a good indication of the approximate amount of delayed foliation to be expected in later-blooming commercial varieties such as J. H. Hale may be obtained. Delay in leafing of lateral buds and evergreen behavior of terminal shoots on early varieties was closely correlated with marked delay and serious decrease in crop of such varieties as Mayflower and Boston nectarine. It should be noted that the index number of St. Helena may be low due to (a) very cold weather as in 1937, or (b) very few 40 degrees F hours as in 1940. The interpretation of the behavior of varieties having very low chilling requirements must be based on careful consideration of the temperature records. In this connection, Chinese Dwarf Mandarin peach reacts more slowly to warm weather than St. Helena following

satisfaction of chilling requirement as shown by later flowering in 1937. This characteristic, if transmitted to hybrids, will be valuable since varieties should not flower too early or late January and early February frost may be hazardous in most of southern California. However, varieties with low chilling requirements have a long flowering period (Fig. 1). Despite late January and February frosts, St. Helena and Australian Saucer had an adequate crop each year from 1936 to 1941. New varieties derived from these might well have equally long flowering periods.

According to Brooks and Philp (3) the season of 1940–1941 was so mild in Davis, California, and vicinity that many varieties were seriously delayed in leafing. In this connection, though the delay was severe in many varieties in southern California as shown by the index numbers for 1941, the effects have not proven as bad as in 1940. Of the varieties severely affected in southern California, which were studied by Brooks and Philp, the most adversely affected at Davis were in their classes III and IV. Accordingly, it seems that all varieties in their class IV and probably those in class III might be unsatisfactory most years in southern California.

In breeding for early-ripening varieties advantage has been taken of the very low chilling requirements of St. Helena and Chinese Dwarf. Australian Saucer not only requires more chilling but also has a flat undesirable fruit shape which, as shown by Lesley (4) behaves as a dominant factor. This would necessitate elimination of three-quarters of the selfed progeny of seedlings from crosses with this variety. Crosses of high quality yellow-fleshed varieties with St. Helena and Chinese Dwarf Mandarin have resulted in seedlings with very low chilling requirements, and fairly good fruit shape and quality. Also selected seedlings having a 70 to 80-day maturity cycle obtained from crosses of the highly colored Babcock with Mayflower and Vainqueur are available. Progenies resulting from intercrossing these selected seedlings are being grown and studied at the Armstrong Nurseries and will be reported in due course.

Summary

Fifty varieties of peaches and nectarines are evaluated in terms of their winter chilling requirements, using their behavior in 1937 and the relatively constant reaction of Lukens Honey as a basis for comparison.

The behavior of varieties of low chilling requirement, such as St. Helena, when observed in connection with the number of 40 degrees F hours accumulated by the time their lateral buds leaf out, is a useful criterion of the degree to which the chilling requirements of later leafing varieties have been satisfied.

The Chinese Dwarf Mandarin and St. Helena have been crossed with high quality commercial varieties and some promising selections made. Mayflower and Vainqueur have been crossed with Babcock, extensive progenies grown and seedlings with 70 to 80-day maturity cycle selected. By further breeding and selection along these lines, it is hoped that high quality early-ripening varieties with short chilling requirements may be secured.

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Ringing in Relation to Fruit Set in the Apple

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THE efficacy of ringing in stimulating fruit set in the apple has been investigated at irregular intervals during the last two decades. Heinicke (2) reported in 1924 an increase in the set of the varieties Arkansas, Baldwin, Ben Davis, Northern Spy, and Rhode Island Greening in response to this treatment. It received no further attention, however, until Greene (1) in 1937 showed a marked increase in Grimes Golden. Despite these favorable results, ringing had not been recommended for commercial adoption until recently, when Murneek reported favorable results in such light-setting varieties as Arkansas and Minkler (3) and as a result of further work with Rome Beauty, Delicious, Stayman Winesap and other varieties (4, 5) recommended its use commercially (6).

The writer first employed the practice in 1928 in an attempt to increase the set in Stayman Winesap and Delicious. For several years thereafter (1929 to 1931) limited attention was given to the practice, especially with reference to Delicious. The particular objective was to ascertain whether consistently favorable results were to be obtained. During 1939 and 1940 the number of trees and limbs involved in the experiment was considerably greater, as indicated herein.

The trees were growing in the orchards of the Ohio Experiment Station and received annual pruning and fertilization with a nitrogen-carrying fertilizer. Both young bearing and mature trees were involved. Paired branches varying in diameter from 1 to 3 inches and forming V-shaped crotches were carefully selected, as far as possible for similar vigor. From one to eight such pairs, usually five or more, were obtained on each tree. A ring of bark ¼ inch wide was removed, and the wound covered with muslin tape impregnated with wax or with electrician's tape. Care was taken to prevent the tape from touching the exposed cambium when in place and thus preventing uniform healing. All flower clusters which had differentiated laterally were removed at the time of ringing, except in 1940, when they were retained and counted separately from those flower clusters differentiated terminally. In 1939 the flower clusters which had differentiated terminally on spurs were counted separately from those on shoots. The count of fruits set was taken after the first and after the second (June) drop. The time of ringing varied from the pink to the full bloom stages. Unless otherwise stated, the operation was performed just as the flowers were opening to full bloom.

PRESENTATION OF THE RESULTS

Results of 1928 to 1931:—During this period ringing was limited to one to three pairs of limbs on each tree. During 1928 and 1929 the operation was performed during the period ranging from the "pink" to "late pink", whereas in 1931 the ringing was carried out at two different times: April 25, when the flowers were late prepink, and April 30, when they were pink. Delicious, Paragon, and Winesap were

ringed on April 24 during 1931, just as the flowers were turning pink. During both 1928 and 1929, in these limited tests the percentage of flowers setting fruit after the June drop was almost identical on both the ringed and unringed branches.

The data for 1931 are presented in Table I.

TABLE I—EFFECT OF RINGING UPON FRUIT SET (1931)

Relation to Abscission Period	Per Cent of Flowers Setting Fruit: Ringed Branches (Average)	Unringed Branches (Average)	Ringed Minus Unringed	F Value*	5 Per Cent Point
Stayman Winesap, Ringed April 20					
After first drop (11 trees)	18.7	17.5	1.2	0.39	4.96
After second drop (11 trees)	10.0	10.5	−0.5	0.23	4.96
Stayman Winesap, Ringed April 30					
After first drop (11 trees)	21.3	16.6	4.7	20.60†	4.84
After second drop (9 trees)	12.6	12.0	0.6	0.14	5.32
Delicious					
After first drop (10 trees)	14.0	15.2	−1.2	0.76	4.67
After second drop (9 trees)	7.5	7.6	−0.1	0.03	4.75
Paragon					
After first drop (2 trees)	14.9	8.9	6.0	30.01	161.45
After second drop (2 trees)	12.1	7.1	5.0	18.71	161.45
Winesap					
After first drop (3 trees)	7.7	10.2	−2.5	1.43	18.51
After second drop (2 trees)	6.7	6.9	−0.2	0.01	161.45

*Snedecor (7). †Significant at 1 per cent point.

It is to be noted that in only one instance with the four varieties was a significant difference in favor of ringing obtained. This was after the first drop on the Stayman Winesap branches ringed April 30. The data further indicate that rather large differences may exist between the set of ringed and unringed branches when a few trees are involved without such differences being significantly statistically.

Results During 1938:—In 1938 four to five pairs on one tree each of Arkansas, Minkler, and Stayman Winesap were ringed, whereas two trees of Paragon were used. Since a severe frost occurred shortly after the first drop, the results obtained are of only limited value. These light-setting varieties, however, offered no previous indication of a definitely favorable response to ringing.

Results During 1939:—During 1939 the ringing was performed on May 8, just before the flowers reached full bloom (terminal flowers open). The varieties, Delicious, Grimes Golden, Minkler, Nero, Paragon, Rhode Island Greening, Stayman Winesap, Turley, and Winesap were involved in the treatment, which included 30 trees and 116 pairs of branches.

The data are presented in Table II. It is to be noted that in not a single instance was a significant difference obtained in favor of ringing. Neither were the results on any single tree significant in this direction. As a matter of fact, in the case of the flowers differentiated on spurs in Arkansas and Nero, there was a significant difference in the opposite direction, in favor of the unringed branches. The ringed portion

TABLE II—EFFECT OF RINGING UPON FRUIT SET (1939)

Relation to Abscission Period	Number of Trees	Pairs of Branches	Per Cent of Flowers Setting Fruit: Ringed Branches (Average)	Unringed Branches (Average)	Ringed Minus Unringed	F Value*	5 Per Cent Point
			Stayman Winesap				
Shoot—after first drop ..	8	33	5.1	4.9	0.2	0.01	4.03
after second drop.	8	33	4.1	4.3	−0.2	0.01	4.03
Spur—after first drop ...	8	33	4.2	5.5	−1.3	2.57	4.03
after second drop.	8	33	3.8	4.8	−1.0	2.39	4.03
			Paragon				
Shoot—after first drop...	3	15	0.7	1.3	−0.6	0.37	4.26
after second drop	3	15	0.6	1.1	−0.5	0.37	4.26
Spur—after first drop....	3	15	0.4	2.2	−1.8	0.87	4.26
after second drop .	3	15	0.3	2.1	−1.8	0.88	4.26
			Delicious				
Shoot—after first drop. .	2	8	1.2	0.9	0.3	0.52	4.75
after second drop	2	8	1.4	0.8	0.6	1.95	4.75
Spur—after first drop....	2	8	1.1	0.6	0.5	4.28	4.75
after second drop.	2	8	1.0	0.6	0.4	3.50	4.75
			Winesap				
Shoot—after first drop .	3	12	3.7	4.8	−1.1	0.23	4.41
after second drop	3	12	4.2	4.8	−0.6	0.18	4.41
Spur—after first drop .	3	12	5.0	6.0	−1.0	1.50	4.41
after second drop.	3	12	4.7	5.6	−0.9	1.25	4.41
			Rhode Island Greening				
Shoot—after first drop ..	3	8	2.4	4.2	−1.8	0.67	4.96
after second drop	2	6	1.0	3.1	−2.1	1.45	5.32
Spur—after first drop....	4	11	5.1	5.1	0.0	0.00	4.60
after second drop.	2	6	6.4	5.4	1.0	0.10	5.32
			Turley				
Shoot—after first drop...	2	8	5.7	3.3	2.4	0.91	4.75
after second drop.	2	8	5.6	3.1	2.5	1.08	4.75
Spur—after first drop. ..	2	8	1.0	0.7	0.3	0.52	4.75
after second drop.	2	8	0.8	0.6	0.2	0.25	4.75
			Arkansas				
Shoot—after first drop...	1	6	0.6	3.3	−2.7	0.74	6.61
after second drop.	1	6	0.6	3.3	−2.7	0.74	6.61
Spur—after first drop....	1	6	0.5	2.2	−1.7	10.30	6.61
after second drop..	1	6	0.5	2.2	−1.7	10.30	6.61
			Nero				
Shoot—after first drop...	1	8	2.8	7.7	−4.9	3.33	5.59
after second drop	1	8	2.8	6.6	−3.8	2.49	5.59
Spur—after first drop....	1	8	1.3	4.6	−3.3	18.46†	5.59
after second drop..	1	8	1.2	4.3	−3.1	13.25†	5.59
			Minkler				
Shoot—after first drop...	1	6	8.3	2.7	5.6	2.47	6.61
after second drop.	1	6	7.1	2.1	5.0	2.65	6.61
Spur—after first drop ..	1	6	3.4	4.0	−0.6	0.07	6.61
after second drop..	1	6	3.1	3.6	−0.5	0.09	6.61

*Snedecor (7). †Significant at 1 per cent point.

was not injured by the operation as far as could be visibly determined. Furthermore, in Paragon, Delicious, Turley, Arkansas, and Minkler the set after the June drop on both the ringed and unringed branches corresponded to less than a full commercial crop.

Results During 1940:—In 1940 ringing was carried out on several of the same varieties just as the flowers were opening (May 13). Eight varieties involving 27 trees and 119 pairs of branches were employed. The number of trees of each variety ranged from 1 to 10. The results are presented in Table III. Significant differences in favor

TABLE III—EFFECT OF RINGING UPON FRUIT SET (1940)

Relation to Abscission Period	Number of Trees	Pairs of Branches	Per Cent of Flowers Setting Fruit			F Value*	5 Per Cent Point
			Ringed Branches (Average)	Unringed Branches (Average)	Ringed Minus Unringed		
Stayman Winesap							
Terminal—after first drop....	10	47	14.5	11.9	2.6	4.35	3.97
after second drop..	10	47	13.6	11.0	2.6	4.44	3.97
Lateral—after first drop......	10	40	5.2	4.1	1.1	0.58	3.97
after second drop ...	10	40	5.1	3.4	1.7	1.25	3.97
Paragon							
Terminal—after first drop....	6	25	6.1	5.7	0.4	0.91	4.10
after second drop..	6	25	4.9	2.4	2.5	13.99†	4.10
Lateral—after first drop......	6	25	4.8	1.8	3.0	6.58	4.10
after second drop....	6	25	2.7	0.3	2.4	16.77†	4.10
Turley							
Terminal—after first drop ...	3	11	10.9	7.7	3.2	1.68	4.49
after second drop..	3	11	10.1	5.0	5.1	7.49	4.49
Lateral—after first drop......	3	11	4.5	0.7	3.7	7.82	4.49
after second drop ...	3	11	2.1	0.4	1.7	5.35	4.49
Winesap							
Terminal—after first drop....	3	10	8.1	6.2	1.9	1.38	4.60
after second drop..	3	10	5.4	3.1	2.3	6.55	4.60
Lateral—after first drop......	3	9	3.7	2.9	0.8	0.36	4.60
after second drop....	3	9	1.7	1.2	0.5	0.42	4.60
Arkansas							
Terminal—after first drop.. .	2	13	6.9	8.0	−1.1	0.52	4.30
after second drop..	2	13	5.4	5.9	−0.5	0.78	4.30
Lateral—after first drop	2	13	5.6	6.9	−1.3	0.27	4.30
after second drop....	2	13	5.2	1.7	3.5	4.20	4.30
Minkler							
Terminal—after first drop....	1	4	20.2	16.9	3.3	1.10	10.13
after second drop..	1	4	18.8	13.0	5.8	1.26	10.13
Lateral—after first drop......	1	4	11.4	2.8	8.6	8.97	10.13
after second drop ...	1	4	9.9	2.4	7.5	5.49	10.13
Nero							
Terminal—after first drop ...	1	6	19.2	15.8	3.4	2.02	6.61
after second drop..	1	6	16.5	11.1	5.4	5.58	6.61
Lateral—after first drop	1	6	4.4	3.6	0.8	0.22	6.61
after second drop ...	1	6	2.9	1.9	1.0	0.53	6.61
Rhode Island Greening							
Terminal—after first drop ...	1	3	21.8	9.5	12.3	27.96	18.51
after second drop..	1	3	11.9	4.3	7.6	27.48	18.51
Lateral—after first drop	1	3	7.6	2.0	5.6	15.24	18.51
after second drop ...	1	3	2.8	0.0	2.8	8.26	18.51

*Snedecor (7). †Significant at 1 per cent point.

of ringing were obtained in the varieties Stayman Winesap, Paragon, Turley, Winesap, and Rhode Island Greening (terminal flower clusters) taken as a whole. The differences, on the other hand, were not significant in Arkansas, Nero, and Minkler.

The data for individual trees of the varieties which as a whole show a significant increase due to ringing are very pertinent in consideration of the response to be expected from ringing. Not a *single* tree of Stayman Winesap gave significant results in favor of ringing. In Paragon ringing produced a significant difference in only *one* of six trees; in Winesap, *one* of three. In Turley no tree taken alone showed a significant difference in favor of ringing and a similar situation was obtained in Arkansas, Nero, and Minkler.

Discussion

Although in some instances, the increased set was significant, in general, ringing did not produce either outstanding or dependable results in the relatively light-setting varieties involved. In 1940, for instance, where the variety as a whole showed a significant increase (5 per cent point) this increase was scarcely apparent when calculated for individual trees. Only when the data from 10 Stayman Winesap trees were combined, was a significant difference obtained in favor of the practice. Other varieties showed somewhat similar results.

Whereas one pair of branches might indicate a favorable response to ringing, others on the same tree and similarly located might show no response whatsoever. This is one of the outstanding observations. Results varied greatly from branch to branch, tree to tree, season to season, and variety to variety. The reasons for this varied response are unknown. Up to the present, it has not been possible to correlate the response in terms of time of ringing, age of tree, location, or vigor of the branches involved. The varying results may be associated in some way with a dissimilar physiological state within the branches which is unapparent externally.

The normal variation between the set of fruit on different branches of the same tree necessitates the use of several trees and a considerable number of paired branches if small differences in set, 2 or 3 per cent, for example, are to be considered significant. A disregard of these variations may make misleading interpretations possible. From present data taken at Wooster, the writer would consider differences of 2 to 3 per cent less than significant unless 8 to 10 pairs of limbs were involved. Several trees with five or more pairs on each would seem to be the minimum number to employ in ringing tests.

The data presented herein do not justify the practice of ringing, under Ohio conditions, to increase the set of the light-setting apple varieties. Certain of these varieties are triploid and possess considerable egg cell sterility. For this reason, effective cross-pollination, together with maintenance of excellent vigor, seems preferable as a means of maintaining maximum fruit set for these varieties, several of which have never been grown satisfactorily from a commercial viewpoint, largely because of their precarious fruit-setting capacity.

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Effect of Indolebutyric Acid Upon Tomato Fruit Set and Development

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THAT fruits of the tomato can be produced without pollination and fertilization, and that certain chemicals stimulate such development, have been demonstrated by several investigators. But the optimum conditions for the production of these fruits, both of the maximum number and size, have not yet been established. This paper is a partial report of experiments carried on to determine whether indolebutyric acid, found to be particularly effective in producing such fruits, will induce a high proportion of fruits from treated flowers, whether the fruits will compare in size with seeded fruits, and whether the parenchymatous tissue elaborated by the placenta will develop extensively during fruit growth. Such information is basic in determining whether these, or similar materials, apart from their contribution to scientific knowledge, are of practical value to the horticultural industry.

Treatment of Plants

The plants were of the Globe variety (strain A) and were grown either in a ground bed or in pots in the greenhouses of the Experiment Station at Wooster. Those in pots were repotted, as necessary, to accommodate a progressively larger root system and thereby maintain a vigorous growth. The soil in the pots was top-dressed frequently with ammonium or potassium nitrate. Each flower of every cluster was separately tagged; its treatment was recorded; and the individual fruits were weighed. Many were examined internally at maturity. Unless otherwise stated, the stamens and style of all treated flowers were severed before treatment. Exceptions occur as shown in Table II, series III, in those instances where the material was applied in spray form to flowers which were either intact or from which the stamens only had been removed.

In series I, 1940, the plants were bedded on January 4. A portion received additional illumination (500 watt Mazda lamps, 30 inches above the plants) to supplement daylight during the period of short days and light of low intensity. The plants of series II and subsequent series were grown in pots, with the exception of series I, 1941.

In selecting the various flowers for treatment, definite orders were followed within the cluster to discount differences in fruit size (and set) due to position. For example, a given treatment was applied to flowers 1 and 3 of half the plants and flowers 2 and 4 of the remaining half. Other arrangements were employed depending upon the number of treatments within a cluster.

Effect of Competition Between Seeded and Seedless Fruits

Previously reported work involved the treatment of flowers which did not compete for food materials and water either within the same

TABLE I—EFFECT OF INDOLEBUTYRIC ACID IN LANOLIN PASTE UPON FRUIT SET AND DEVELOPMENT (1940)

Order of Cluster Development	0.5 Per Cent Lanolin Paste			0.3 Per Cent Lanolin Paste			0.1 Per Cent Lanolin Paste			Cross-Pollinated			Self-Pollinated		
	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers	Per Cent Set	Average Weight of Fruits (Grams)
Series I															
1. Jan 29 to Feb 10 ...	123	87.5	165.3	—	—	—	15	66.7	93.2	111	82.9	128.0	59	59.3	114.2
2. Feb 2 to Feb 26....	45	86.7	109.7	—	—	—	99	65.7	111.7	24	87.5	102.3	168	75.6	117.0
3. Feb 8 to Mar 4.....	—	—	—	—	—	—	135	68.9	84.3	191	83.2	103.4*	—	—	—
4. Feb 15 to Mar 11...	—	—	—	—	—	—	145	83.4	90.2	—	—	—	144	95.8	151.7
5. Feb 26 to Mar 18...	68	72.1	151.4	90	93.3	167.5	76	59.2	91.6	—	—	—	—	—	—
Series II															
3. Feb 23 to Mar 13...	—	—	—	18	88.9	193.7	20	100.0	126.6	—	—	—	160	98.1	200.4
4. Mar 7 to Mar 22 ...	—	—	—	19	89.5	192.9	20	70.6	151.9	—	—	—	150	96.7	207.7
5. Mar 11 to Mar 30...	—	—	—	17	47.1	195.5	20	55.0	131.5	—	—	—	—	—	—
Series III															
2. Mar 19 to Apr 24...	50	56.0	171.8	50	90.0	225.6	—	—	—	—	—	—	—	—	—
3. Mar 27 to Apr 5....	42	78.6	230.8	45	100.0	376.3	—	—	—	—	—	—	—	—	—
4. Apr 3 to Apr 10.....	44	68.2	243.7	49	75.5	277.0	—	—	—	—	—	—	—	—	—

*Indicates that pollen sample used showed low viability.

cluster or, in fact, on the same plant, with flowers normally pollinated and fertilized. Under these conditions, sets as high, and fruits as large, developed from treated as from pollinated flowers (1). On the other hand, the first experiment reported herein (Table I) is concerned with treated and pollinated flowers which developed in competition with each other within the same cluster. The effect of this competition on fruit set and size is shown in Tables I to III. The dates appearing in these tables immediately after the order of cluster development indicate the period during which the flowers were treated. The comparison of data in the tables should be made largely within a given cluster. The pollinated flowers comprised three groups in series I (Table I). In one they were pollinated by hand with highly viable pollen from other plants (cross-pollinated) ; in another they were self-pollinated (pollen also transferred by hand) ; and in the third they were pollinated with pollen of low viability. Since indolebutyric acid at 0.5 per cent concentration unexpectedly resulted in some surface russeting in the first and second clusters, a concentration of 0.1 per cent was employed thereafter in series I.

The data to be noted in particular concern cluster 1 and 2 of series I (1940) and clusters 3, 4, and 5 of series II (1940). The most effective concentration of indolebutyric acid was 0.3 per cent in lanolin paste, although in particular clusters and under certain conditions, 0.1 per cent was practically as effective in inducing fruit set. However, the average size of fruits was invariably smaller. For this reason and in view of the hazard of injury at a concentration of 0.5 per cent, 0.3 per cent in lanolin became the standard treatment with which other treatments and materials are to be compared.

Effect of Indolebutyric Acid in Spray as Compared With Paste Form

The effect of indolebutyric acid when applied in spray (water as solvent) as compared with the paste form is also indicated in Table II. Although the concentrations of 0.3 and 0.1 per cent in paste are not exactly equivalent to the concentrations in the spray form, certain conclusions can be drawn. Frequently, although not always, indolebutyric acid in water at a 0.24 per cent concentration, applied either two or three times, resulted in a fruit set similar to that induced by the paste, but the average size of fruits was invariably smaller. A single application of the spray was less effective.

The physiological condition of the plant apparently determined the relative effectiveness of indolebutyric acid applied in either form. In series II, the spray at 0.24 per cent concentration induced a larger set and even larger fruits in the first and second cluster than the weak 0.1 per cent concentration in paste form. In the third, fourth, and fifth clusters, however, the situation was reversed. With active competition between fruits developing on earlier clusters limiting the size of fruit, the material in water seemed less effective than the paste. Similar results have been observed in other series where the material has been applied in both water (spray) and lanolin paste.

Concentrations of 0.14, 0.04, 0.024, and 0.0024 per cents in water,

TABLE II—EFFECT OF INDOLEBUTYRIC ACID IN SPRAY AND PASTE FORM UPON FRUIT SET AND DEVELOPMENT (1940)

Cluster Order	0.3 Per Cent Lanolin Paste			0.1 Per Cent Lanolin Paste			0.24 Per Cent Spray (Water)			Other Spray Concentrations				Self-Pollinated		
	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Concentration	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers	Per Cent Set	Average Weight of Fruits (Grams)
Series I																
6. Mar 4 to Mar 23	137	78	169	—	—	—	149	32	99 (2)*	—	—	—	—	—	—	—
7. Mar 7 to Apr 3	140	65	169	—	—	—	148	70	114 (2)	—	—	—	—	—	—	—
Series II																
1. Feb 1 to Feb 12	—	—	—	42	81	120	21	95	184 (2 S)	.04	61	15	55 (1)	—	—	—
							71	90	112 (1)							
2. Feb 10 to Mar 5	—	—	—	26	73	113	129	85	131 (2 S)	—	—	—	—	36	94	149
							42	67	108 (2)							
3. Feb 23 to Mar 13	18	89	194	20	100	127	123	73	81 (2 S)	—	—	—	—	160	98	200
							33	61	60 (2)							
4. Mar 7 to Mar 22	19	90	193	20	71	152	162	41	78 (2 S)	—	—	—	—	150	97	208
5. Mar 11 to Mar 30	17	47	196	20	55	132	82	43	94 (2 S)	.14	150	42	76 (2)	—	—	—
Series III																
1. Mar 5 to Mar 19	94	95	179	—	—	—	95	84	121 (2)	—	—	—	—	—	—	—
2. Mar 19 to Apr 2	50	90	226	—	—	—	45	42	150 (3)	—	—	—	—	50	56	171
							44	77	176 (3 N)							
3. Mar 27 to Apr 5	45	100	376	—	—	—	47	98	156 (3)	—	—	—	—	42	79	231
							44	100	253 (3 N)							
4. Apr 3 to Apr 10	49	76	277	—	—	—	47	89	112 (3)	—	—	—	—	44	68	244
							50	90	136 (3 N)							
5. Apr 9 to Apr 26	80	55	196	—	—	—	87	77	100 (3)	—	—	—	—	—	—	—

*Figures in parenthesis refer to number of applications.
S indicates style not removed.
N indicates flower not emasculated.

although tested in a limited way, were distinctly inferior in all respects to 0.24 per cent in water. Occasionally, 0.14 per cent in water might induce as large a set as the stronger concentration, but the size of fruit was distinctly smaller. Furthermore, the fruits resulting from weaker concentrations contained less ovule development and were more meaty and firm and contained less of the desirable parenchymatous tissue in the locules.

Effect of Indolebutyric Acid Applied in Paste as Compared With Emulsion Form

In view of the obvious ease of application, as well as the desirability of a form which requires only one application, attention was given to an emulsion. Several emulsions were employed, but the one used during and since 1940 is somewhat similar to that described by Winklepleck and McClintock (2) except that it was more liquid, being somewhat of the consistency of milk. More than ten series of plants have been grown continuously as a means of comparing indolebutyric acid in emulsion with the paste form. The plants were grown largely in pots, with the exception of series I, 1941, which involved the same ground bed as did series I, 1940. Representative data showing the relative effect of the chemical in paste and emulsion (spray) are presented in Table III and Fig. 1.

Data obtained to the present show the emulsion at 0.3 per cent concentration to be as effective as the paste under practically all conditions. Furthermore, under certain conditions, it was superior, not only in stimulating fruit set, but also in inducing larger fruits at maturity. In fact, on the first and second clusters, or under conditions where competition with fruits developing on earlier clusters is not severe, the paste and emulsion may be equally effective. On the other hand, under severe competition the emulsion seems somewhat more effective. Typical results are presented in Fig. 1, in which the growth curves of fruits resulting from self-pollination, and from treatment with the paste and the emulsion, are presented. The superiority of the emulsion over the paste is slight in series I, cluster 2, but more pronounced in cluster 3. In series II, the emulsion was superior in all clusters.

In cluster 4 (series I) the emulsion at 0.2 per cent concentration induced fruit size greater than that attained by fruits from self-pollinated flowers. The data obtained up to the present indicate that 0.2 per cent may be equal in effectiveness to the 0.3 per cent concentration in stimulating fruit set and development.

Despite the strikingly favorable results produced by the emulsion, a disturbing factor has arisen under certain environmental conditions. A disorder closely resembling blossom-end rot, if not actually the disorder itself, develops on many fruits as a result of the emulsion application. Very little of the disorder is observed when the chemical is applied in lanolin paste, even at the same concentration. Environmental conditions conducive to high transpiration result in serious loss due to the disorder. On fruits developing from flowers of the first and second clusters during January and February, when transpiration is low,

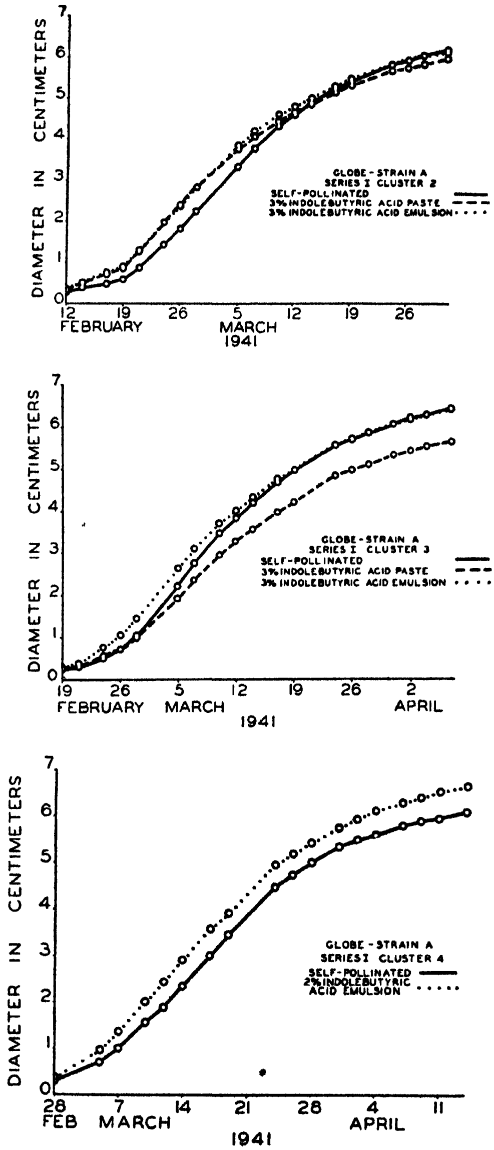

FIG. 1. Growth curves of fruits produced by indolebutyric acid in pastes and emulsions and by self-pollination (Series I, 1941).

practically no injury is observed. Pollinated flowers to which the emulsion is applied also develop the disorder even though they possess a high seed content, and this result indicates that no relationship exists between lack of seed development and the injury. Owing to this disorder the use of lanolin emulsion, as at present constituted, is extremely hazardous except under conditions of low transpiration.

Another complication is the effect of the chemicals upon stylar development. Following application of indolebutyric acid as a spray (water or emulsion) considerable enlargement of the style may occur unless it has been previously severed near its base. Thus in extreme instances, pear-shaped fruits are produced. For this reason, it is necessary to remove a very large proportion of the style if normal-shaped fruits are to be obtained, regardless of the fact that the material in spray form is effective in producing fruits even when the styles of the flowers are left intact. Contrary to this effect with the spray, with the paste form it is essential in order to produce fruits of any kind to apply the chemical on either the ovary or the much-shortened style.

The writer was concerned as to whether the abnormal enlargement would occur if the style had already been traversed with pollen tubes.

TABLE III—EFFECT OF INDOLEBUTYRIC ACID IN EMULSION AND PASTE FORM UPON FRUIT SET AND DEVELOPMENT (1941)

Cluster Order	0.3 Per Cent Lanolin Paste			0.3 Per Cent Lanolin Emulsion			0.2 Per Cent Lanolin Paste			0.2 Per Cent Lanolin Emulsion			Self-Pollinated		
	Number of Flowers Treated	Per Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per-Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per-Cent Set	Average Weight of Fruits (Grams)	Number of Flowers Treated	Per-Cent Set	Average Weight of Fruits (Grams)	Number of Flowers	Per-Cent Set	Average Weight of Fruits (Grams)
Series I															
1. Jan 23 to Feb 13...	57	96.5	136.1	54	92.6	139.3	—	—	—	—	—	—	51	90.2	154.2
2. Feb 3 to Feb 25 ...	95	71.6	142.0	97	88.7	160.1	—	—	—	—	—	—	91	87.1	142.9
3. Feb 12 to Mar 10 ..	101	62.4	106.1	114	93.0	142.9	—	—	—	—	—	—	103	87.4	127.5
4. Feb 19 to Mar 24...	—	—	—	74	87.8	146.1	30	6.7	0.0	109	78.0	150.6	107	83.2	128.4
5. Mar 4 to Apr 7. ..	134	30.6	80.3	—	—	—	144	28.5	93.4	—	—	—	—	—	—
6. Mar 17 to Apr 19..	—	—	—	146	98.6	230.4*	—	—	—	—	—	—	132	90.0	183.7
7. Mar 24 to Apr 26..	—	—	—	121	85.1	156.0	—	—	—	140	88.6	168.3	24	83.3	177.4
8. Mar 31 to Apr 30..	—	—	—	138	81.9	155.1	—	—	—	139	79.9	141.5	—	—	—
9. Apr 7 to Apr 30....	—	—	—	129	89.9	153.3	—	—	—	131	84.0	143.8	—	—	—
10. Apr 14 to Apr 30 ..	56	85.7	147.9	57	91.2	175.1	—	—	—	—	—	—	36	50.0	153.8
Series II															
1. Feb 13 to Mar 14.	18	83.3	158.8	15	100.0	203.2	—	—	—	—	—	—	19	89.5	168.3
2. Feb 25 to Mar 12.	23	52.2	128.8	25	64.0	167.8	—	—	—	—	—	—	24	75.0	158.3
3. Mar 4 to Mar 15...	23	21.7	144.2	23	60 9	171.0	—	—	—	—	—	—	26	73.1	170.6
4. Mar 11 to Mar 24..	—	—	—	19	10.5	296.7	—	—	—	—	—	—	20	70.0	175.5

*Flowers pollinated before treatment. Compare with self-pollinated group.

This would not be important in case indolebutyric acid was employed to produce seedless fruits, since in this instance stylar removal would be obligatory. On the other hand, in case the chemical was employed to supplement pollination and fertilization, it would be important to know whether growth of a few pollen tubes would make such removal unnecessary. The data available indicate less tendency toward stylar enlargement provided tubes have traversed the stylar tissue. However, under conditions when the chemical would be most helpful, that is, when little or no viable pollen is available, almost complete removal of the style seems at present necessary.

Effect of Indolebutyric Acid Upon Pollinated Flowers

The discussion of data up to the present has been largely centered upon the response of flowers emasculated previous to treatment. However, the writer is particularly concerned with the effect of indolebutyric acid upon flowers which have been left intact, flowers, for example, which possess little or no viable pollen in their stamens, flowers which in consequence would not set fruit or would develop into small, more or less malformed fruits with little or no parenchymatous tissue within the locules at maturity. In northern greenhouses this condition is frequently found in the first and second clusters from January to March. The problem is to determine the extent to which this (or other chemicals) may be employed, not only to improve fruit setting, but also to promote the development of fruits of better quality.

Several series of plants have been employed to determine the effect of indolebutyric acid upon flowers which have not been emasculated and which are known to possess little or no viable pollen. In series I, 1940, three lots of flowers were employed. In one lot the flowers were pollinated with highly germinable pollen (termed cross-pollinated). Another lot was self-pollinated, and the pollen was low in viability. The third group was emasculated and pollinated with pollen of low viability previously collected from other flowers. Ninety-six hours after pollination the styles were removed from one-half of the flowers of each lot, and the ovary was treated with indolebutyric acid in paste form. The effect upon fruit growth was determined by measurements of the diameter, made by means of a vernier caliper at intervals until maturity.

Cross-Pollinated Flowers:—(Series I, Fig. 2). Pronounced growth was immediately stimulated in the treated flowers, but the resulting fruits were similar in size at maturity to those resulting from cross-pollination. The fruits from the untreated flowers contained a satisfactory seed content, and the locules were, in general, well filled with gelatinous pulp. The fruits from treated flowers, however, were still distinctly superior in these respects.

Self-Pollinated Flowers:—The first effect of the chemical, apart from immediate stimulation in growth, was an increased fruit set. Only 60 per cent of the untreated selfed flowers set fruit as opposed to 100 per cent of the treated flowers. Furthermore, even the weak concentration of 0.1 per cent resulted in larger fruits at maturity (Fig. 2). This result was probably due to the fact that the fruits de-

veloping from untreated flowers showed rather poor seed development and contained much less gelatinous pulp than fruits developed from cross-pollinated flowers (Fig. 3). Many locules were devoid of seeds and contained no parenchymatous tissue, and the walls of the locules were frequently contiguous. On the other hand, the fruits from the treated flowers were well filled out, despite poor seed development, and showed extensive gelatinous pulp (Fig. 4). In some of these fruits, only one to three seeds were present. The results indicate the pronounced effect of indolebutyric acid in supplementing fertilization, stimulating fruit set, increasing fruit size, and improving the development of the parenchymatous tissue.

Flowers Pollinated With Pollen of Low Viability:—In this instance, 90 per cent of the treated, as opposed to 60 per cent of the untreated, flowers set fruit. The same differences in fruit growth (Fig. 2) and in quality of fruit occurred as in the self-pollinated individuals.

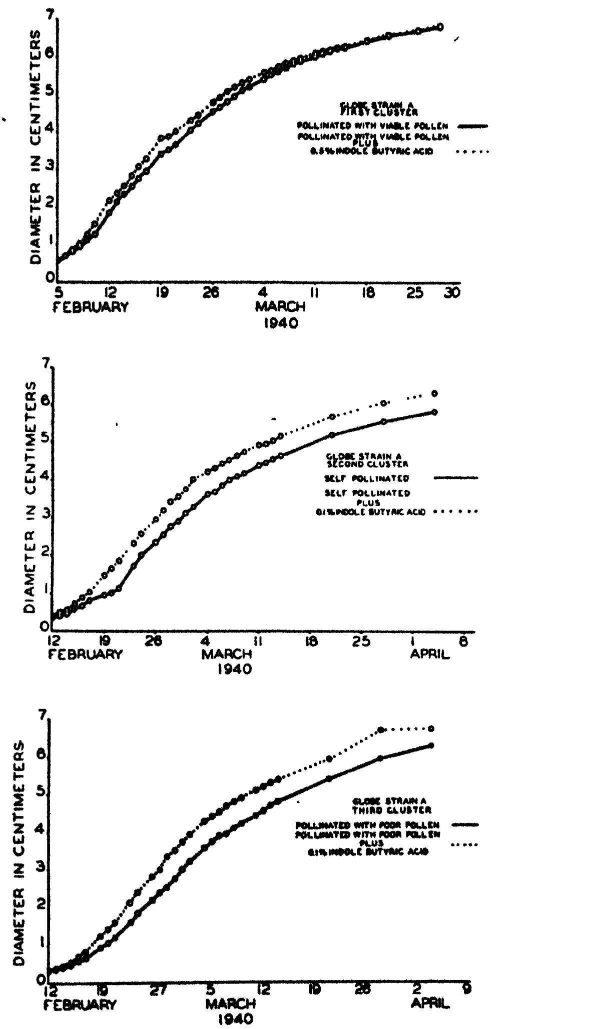

FIG. 2. Growth curves of fruits from pollinated flowers, with and without additional treatment of indolebutyric acid (Series I, 1940).

It is further to be noted that in series III, Table II, flowers in the second, third, and fourth clusters were treated with indolebutyric acid in spray form without emasculation. Emasculation was unnecessary, since by means of several nitrogen applications, the pollen of all flowers up to and including the fourth cluster was made nonviable. Fruits identical internally to those produced following pollination with pollen of low viability and treatment with indolebutyric acid were obtained,

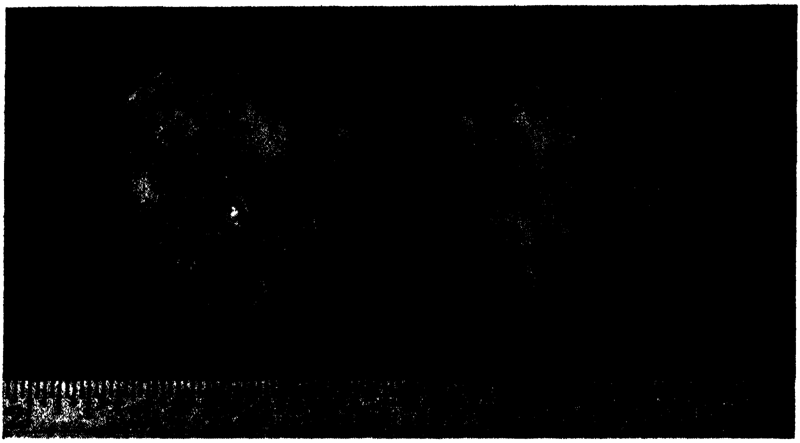

FIG. 3. Cross section of typical fruit from flowers self-pollinated but untreated showing poor seed development and little gelatinous pulp.

although there was considerable stylar enlargement.

Thus indolebutyric acid had pronounced effects upon flowers which had been pollinated with pollen of low viability. Usually, the extent to which the set was increased and the size of fruit was improved depended upon the amount of fertilization and embryonic development which had occurred. Obviously, the less seed development, the more improvement resulted from the application of the chemical. Undoubtedly, indolebutyric acid resulted in increased fruit production and in outstanding improvement of fruit quality.

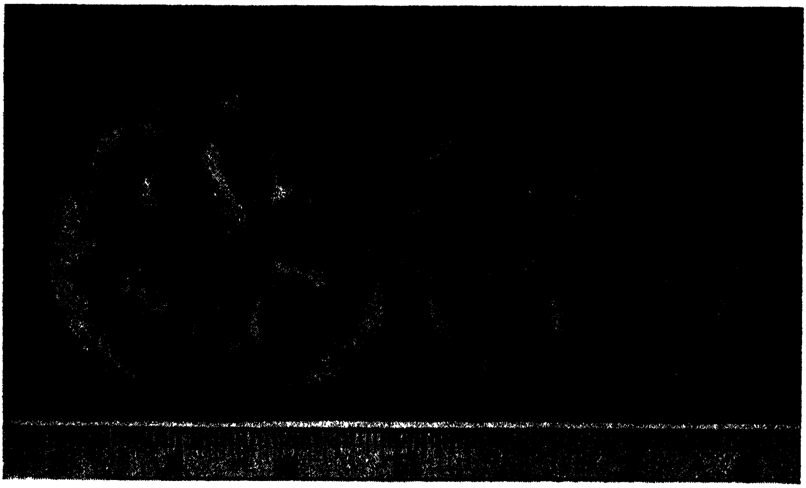

FIG. 4. Cross section of fruit showing typical effect of indolebutyric acid in stimulating development of parenchymatous tissue in locules where seeds are lacking. Fruit is from flowers both self-pollinated and treated.

Summary

Indolebutyric acid proved to be very effective, both in the number and size of fruits produced from treated flowers, and in the extensive development of gelatinous pulp within the locules. Equally pronounced effects were obtained when the chemical was employed to supplement pollen of low viability; (in this case also) the set and quality of the fruit were greatly improved.

The chemical used in a lanolin emulsion was frequently superior to the paste form, except for the fact that it resulted in considerable blossom-end rot. Details of the technique of application need to be improved, but very pronounced effectiveness of the material is unquestioned.

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Modifying the Biennial Bearing Habit in Apples by Spraying to Prevent Fruit Set

By J. R. MAGNESS and L. P. BATJER, *U. S. Horticultural Station, Beltsville, Md.*

EXTENSIVE investigational work has shown that the biennial-bearing habit in apples results from an excess of fruit setting on the trees during the "on" year. When the quantity of fruit on the tree in relation to the amount of foliage which the tree carries is excessive, flower-bud formation for the following year does not occur. Thus, in the season following the "on" year there is an absence of bloom and crop on the trees. Under these conditions excessive fruit-bud formation occurs, with most of the growing points becoming flower buds. Once the biennial bearing habit is established, alternate years of extremely heavy bloom and heavy crop are followed by an absence of bloom and absence of crop. Fruit thinning experiments have shown that if the fruit set is reduced in sufficient amount and sufficiently early in the "on" year, fruit-bud formation will occur and annually repeated crops can be secured. Because of the very short time during which this kind of thinning can be done, however, and the large numbers of fruits which must be removed from biennial trees, correction of the biennial bearing habit by hand thinning is a questionable economic practice under many growing conditions.

Experiments conducted in 1939 (1) and earlier indicated the possibility of killing part of the bloom of apple trees by the use of caustic sprays such as tar oil distillate (TOD) and di-nitro-ortho-cyclo-hexyl-phenol (DNO). All of the trees sprayed in 1939, in which the set of fruit was reduced to not more than one fruit per 10 blossom clusters on heavily blooming trees, formed a good crop of fruit buds and set good crops of fruit in 1940. Consequently experiments were continued in 1940 to study the effect of different concentrations of these materials on set of fruit. Since the earlier work had indicated that the delayed cluster bud or early pink stage was most satisfactory for preventing fruit set, all the trees used in 1940 were sprayed while in this stage.

EXPERIMENTS ON OLD YORK IMPERIAL TREES

A block of 13 old York Imperial trees from 25 to 30 feet high and almost completely biennial were available for use at the University Experiment Farm, Kearneysville, West Virginia.[1] These trees were sprayed at the early pink stage, using the spray materials listed in Table I. Check trees and treatments were randomized throughout the block as indicated by the tree numbers, the first number representing the row and the second number the tree in the row. Pollination conditions were good for all trees. As thorough spray coverage as possible was obtained, one man spraying the trees from the top of a tank mounted on a truck, another spraying from the ground. On such tall trees it is necessary to direct the spray upward to reach the tops, and

[1]The cooperation of Mr. Edwin Gould, Superintendent of the University Experiment Farm, is gratefully acknowledged.

TABLE I—EFFECT OF BLOSSOM REMOVAL SPRAYS, APPLIED AT LATE CLUSTER-BUD STAGE, ON FRUIT SET, YIELD, AND FRUIT-BUD FORMATION (OLD YORK IMPERIAL TREES, KEARNEYSVILLE, WEST VIRGINIA, 1940)

Treatment 1940	Tree No	Yield (Bu) 1938	Yield (Bu) 1939	Fruit Set Per 100 Clusters (1940)	Yield (Bu) (1940)	Estimated Portion of Growing Points Blossoming (Per Cent) 1941
Check	3–3	63	0	33.2	44.5	0 (except 1
	5–3	33	2	29.2	25.0	0 limb)
	7–1	41	1	44.0	42.0	0
TOD* .8 per cent	4–3	36	0	12.2	13.0	8–10
	6–6	29	2	10.0	17.5	10
TOD 1.6 per cent	2–2	44	0	13.8	20.5	10
	7–2	40	1	27.2	26.0	1
TOD 1.6 per cent, repeat spray	4–4	38	2	5.9	5.0	60
	7–6	42	1	2.4	3.3	50
DNO† dormant strength	3–6	45	0	7.0	9.7	15
	7–4	46	1	7.8	10.5	55
DNO one-half dormant strength	4–2	32	1	5.2	10.7	35–40
	7–5	31	1	4.8	7.0	40

*TOD = Tar oil distillate.
†DNO = A mixture of 4 ounces di-nitro-ortho-cyclo-hexyl-phenol in 1 gallon of oil with goulac-bentonite emulsifier, used at the rate of 2 gallons per 100 gallons of water for dormant strength, and 1 gallon per 100 gallons of water for one-half dormant strength.

in general, hitting blossoms is more difficult and subsequent killing is less complete in the tops of such tall trees than on the lower branches.

The yield of these trees for 1938 and 1939, shown in Table I, indicates the degree of the biennial habit, since no treatments were applied during either of these two years. Data in the column headed "Fruit set per 100 clusters" were secured by counting 2,000 or more blossom clusters on four large limbs in each tree. Fruit set on these limbs was counted when the last drop was largely over.

The per cent blossoming in 1941 was based on careful estimates made at bloom time. A bloom on 20 per cent of the growing points is normally sufficient for a full crop of fruit. Thus in these old biennial trees, of the 10 sprayed five had ample bloom for a full crop in 1941 and four others bloomed enough for at least half a crop. There was practically no bloom on the check trees. Only when the set in 1940 was reduced to not more than 10 fruit per 100 growing points was a sufficient bloom for a full crop in 1941 obtained.

We have no explanation of the failure of the 1.6 per cent tar oil distillate in this experiment to more effectively reduce the set on the trees sprayed only once with this material. Other trees sprayed from the same tank mixture had their fruit set effectively reduced.

The treatment with tar oil distillate 1.6 per cent repeat spray represented two applications of this material made 5 days apart, the first being at the early pink and the second at the late pink stage. This treatment was applied to determine the possibility of completely removing the crop by such repeat sprays, a practcie which, under some conditions, might be desirable from the standpoint of codling-moth control. The repeat sprays on these very large trees did not completely prevent fruit set, apparently because of the difficulty of hitting all the

blossoms in such large trees, even with two applications.

On these trees the DNO at dormant and half-dormant strength appeared somewhat more effective than the tar oil distillate in preventing fruit set. The half-dormant strength was fully as effective as full dormant, and apparently was strong enough to prevent the setting of any blossoms that were well hit.

Spraying Tests on Younger Trees

Additional tests of these same materials on younger York Imperial, Stayman Winesap, and Gano trees about 18 years of age, and which consequently could be thoroughly hit with the spray materials, are reported in Table II. In these tests on York Imperial, .8 per cent TOD and one-half dormant-strength DNO decreased the set to about one-third that of the check trees. The 1.6 per cent TOD and full dormant strength DNO reduced the set still more drastically, while the TOD repeat spray resulted in almost complete removal of the crop. A few scattered apples remained on the trees, however.

TABLE II—Effect of Blossom-Removal Sprays on 18-Year-Old Trees (York Imperial, Stayman Winesap, and Gano Apples, Kearneysville, West Virginia, 1940)

Treatment	York Imperial				Stayman Winesap			Gano		
	Tree No	Fruits Set Per 100 Clusters	Yield (Bu)	Estimated Portion Growing Points Blossoming 1941 (Per Cent)	Tree No	Fruits Set Per 100 Clusters	Yield (Bu)	Tree No	Fruits Set Per 100 Clusters	Yield (Bu)
Check	2–4	24.0	15.0	0	8–9	16.0	16.5	4–11	82.0	20.2
	5–6	17.0	17.5	7	7–17	30.0	12.0	4–17	74.0	12.7
	7–3	20.2	12.5	6	8–21	40.0	17.5	—	—	—
TOD* .4 per cent	—	—	—	—	8–10	5.2	4.5	4–13	35.0	9.2
	—	—	—	—	7–14	4.8	4.2	5–16	41.0	8.2
	—	—	—	—	9–21	8.0	6.1	—	—	—
TOD .8 per cent	1–4	5.0	3.7	20	7–10	9.2	4.5	5–12	13.1	6.2
	1–2	8.5	4.7	—	7–15	11.0	9.0	4–18	40.0	6.5
	9–6	2.1	4.0	25	10–22	3.1	2.7	—	—	—
TOD .8 per cent repeat	—	—	—	—	7–11	0.7	0.5	—	—	—
	—	—	—	—	8–13	0.2	0.2	—	—	—
	—	—	—	—	9–19	0.0	0.2	—	—	—
TOD 1.6 per cent	1–3	5.0	1.3	30	—	—	—	—	—	—
	8–3	6.2	7.7	12	—	—	—	—	—	—
	9–4	3.2	3.5	50	—	—	—	—	—	—
	6–7	0.9	2.0	20	—	—	—	—	—	—
TOD 1.6 per cent repeat	1–5	0.2	0.1	20	—	—	—	—	—	—
	5–7	1.4	0.6	25	—	—	—	—	—	—
	6–5	0.0	0.1	60	—	—	—	—	—	—
	8–7	1.8	1.7	65	—	—	—	—	—	—
DNO† one-half dormant strength	2–6	16.0	6.5	10	7–12	2.5	1.5	5–8	5.6	—
	8–4	4.0	4.7	10	8–12	2.4	1.7	4–16	5.4	—
	9–7	13.5	4.5	25	9–14	2.4	3.1	—	—	—
DNO, dormant strength	4–5	0.1	0.1	30	—	—	—	—	—	—
	8–6	0.8	0.2	22	—	—	—	—	—	—
	9–1	2.5	1.7	45	—	—	—	—	—	—

*TOD = Tar oil distillate.

†DNO = A mixture of 4 ounces di-nitro-ortho-cyclo-hexyl-phenol in 1 gallon of oil, used at the rate of 2 gallons per 100 gallons of water for dormant strength, and 1 gallon per 100 gallons of water for one-half dormant strength.

With Stayman Winesap even .4 per cent TOD reduced the set to only about one-third that on the checks. TOD .8 per cent was not appreciably more effective than .4 per cent. The .8 per cent repeat, however, removed practically all of the fruit. With Gano, on which many of the fruit buds are on relatively long shoots, the proportion of reduction was similar.

The younger trees of York Imperial were not fully biennial and the other varieties were annual producers, but had a heavy bloom in 1940. The results are indicative of the amount of reduction in set that might be expected from these lower concentrations of materials when applied to trees that can be thoroughly covered with sprays directed more or less horizontally into the tops rather than upward from below.

A limited test on two Yellow Transparent trees, using .8 per cent TOD, indicated that prevention of fruit set on this variety is more difficult than with the others studied. A set of about 50 fruits per 100 blossom clusters was obtained on the sprayed trees.

Discussion

The results of the 1940 spraying substantiated those obtained earlier in indicating that tar oil distillate at .8 per cent concentration, thoroughly applied, is sufficiently strong to prevent the set of a large proportion of the fruit buds of the varieties investigated except on Yellow Transparent. Di-nitro-ortho-cyclo-hexyl-phenol at one-half dormant strength appeared on the whole to be slightly more effective than tar oil distillate at .8 per cent in preventing fruit set. On the basis of 2 years' results, it would seem unnecessary to use materials stronger than these on the varieties studied, if the objective is to reduce fruit set rather than to eliminate a crop completely.

Fruit that set following the spray treatment was apparently from buds not sufficiently developed at the time of spraying to be thoroughly hit, or too well protected by branches or by their position on the tree, for the spray material to hit the actual buds. Even with a thorough job of spraying, it has not been possible under Potomac Valley conditions to remove the crop completely with one spray application.

Results of the commercial use of tar oil distillate sprays in the Wenatchee, Washington, area in 1940 were extremely satisfactory from the standpoint of practically completely removing the crop, which was the objective of the spraying. A single application of 2 per cent tar oil distillate was used, and almost no apples set on the trees.

During the past 8 years in the United States the even-numbered years have been relatively short apple crop years, with much better prices prevailing than during the odd-numbered years. Many orchards, however, have been producing their main crop during the odd-numbered years, with poor financial results to the grower. The treatments outlined indicate a method by which the "on" year for parts of such biennial orchards can be changed and the orchard production as a whole be made more uniform from year to year, this being accomplished without the complete loss of a crop. It would appear to merit the serious consideration of any grower who has certain varieties in a strongly biennial condition. The grower might bring about more

uniform production by thoroughly spraying approximately half of each tree of biennial varieties, or by spraying all of the trees in a part of biennial blocks.

Coverage must be very thorough if the crop of biennial trees or parts of trees is to be reduced sufficiently by one spray application to insure a crop for the following year. This is particularly true of large trees, where the spray must be directed upwards and the young leaves tend to protect the blossom buds from being well hit.

Finally, these results have been secured through spraying when spur buds are in the late cluster to early pink stages. Earlier spraying has been relatively ineffective, as it is not possible to hit the individual buds. Later there is more foliage on the tree, and the injury resulting to the foliage would tend to decrease fruit-bud formation.

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The Correlation of Trunk Circumference with Weight of Top in Some Double-Worked Apple Trees[1]

By F. N. Hewetson, *Michigan State College, East Lansing, Mich.*

THE relative value of the different methods used to measure tree size is based on the accuracy with which the data so obtained can be correlated with the actual size or weight of the tree. Trees, unlike many other plants, cannot be weighed without putting an end to the life of the tree. It is often very desirable to obtain tree weights, or close estimates of them, at definite intervals, hence the appearance from time to time of various publications giving suggestions as to how such approximate data may be obtained. Twig growth, height and spread of tree, volume of tree, trunk circumference and area trunk cross section have each been used as an index at various times.

The opportunity to test the accuracy of these various methods comes only once in the life-time of a tree, so of necessity such check-ups are somewhat meager. Heinicke (2), working with 4 year McIntosh trees, observed that the relationship between the circumference and the weight in this lot of trees was such that the weight was increased approximately 7.3 times while the circumference was doubled. He was careful, however, to point out that circumference measurements are reliable as a measure of small differences *only* when rather large numbers of approximately similar trees are concerned in the average. Sudds and Anthony (3) worked out a number of correlations with some York and Stayman varieties. Among other correlations they found that when the circumferences of the trees were cubed, they showed a correlation of $.92 \pm 0.17$ with the weight of the tree. Collison and Harlan (1), working with 21 McIntosh trees, obtained a correlation of $.972 \pm .008$ between trunk circumference and tree weight (top). From the figures for trunk circumference they calculated the weight of the tree. When these estimated weights were compared to the actual weights, it was found that the error of such calculated weights ranged from 0.3 per cent to 11.9 per cent with an average of 3.9 per cent.

The real value of the following data and conclusions lies in the fact that they confirm results obtained by other workers using different material under quite different conditions and in that way they help to establish a truth.

In the spring of 1939 it became necessary to remove alternate trees in a block of Steele apple trees in a propagation experiment at East Lansing. These trees were part of an experiment designed to study the effect of different interstocks on the growth and behavior of apple trees. They were planted in the spring and fall of 1932, making them 7- and 6-year-old trees respectively at the time of removal. The soil on which these trees were growing was a Hillsdale sandy loam. The tops of these trees were cut off as nearly as possible at the union of the stock and interstock and in the case of trees on seedling stock, at the union

[1]Journal Article No. 503 (n. s.) from the Michigan Agricultural Experiment Station.

TABLE I—RELATIONSHIP BETWEEN WEIGHT OF TOPS, TRUNK CIRCUMFERENCE AND AREA OF TRUNK CROSS SECTION IN SOME 6- AND 7-YEAR-OLD STEELE TREES

Group	No. of Trees	Trunk Circumference (Cms)	CV Trunk Circumference	Area Trunk Cross Section (Sq Cms)	CV Area Trunk Cross Section	Weight of Tops (Lbs)	CV Weight of Tops	Correlation Between Circumference and Weight	Correlation Between Area Trunk Cross Section and Weight
First Planting, 7 Years Old									
Steele/Northern Spy/seedling	7	28.3 ±2.66	23.0	67.09 ±10.36	37.8	42.2 ±8.61	50.0	0.925 ±0.048	0.945 ±0.049
Steele/Tolman/seedling	8	26.5 ±0.89	8.9	56.30 ±3.86	18.2	34.1 ±4.16	32.2	0.519 ±0.298	0.533 ±0.292
Steele/seedling	35	25.6 ±0.58	13.2	52.93 ±2.37	26.1	30.6 ±1.93	36.7	0.898 ±0.034	0.899 ±0.033
Second Planting, 6 Years Old									
Steele/Fameuse/seedling	13	23.2 ±1.03	15.3	43.79 ±3.78	29.9	24.5 ±2.23	31.6	0.908 ±0.053	0.897 ±0.059
Steele/Tolman/seedling	11	23.1 ±1.19	16.3	43.56 ±4.04	29.3	26.6 ±3.40	40.4	0.957 ±0.028	0.966 ±0.022
Steele/Wolf River/seedling	6	22.1 ±1.43	14.4	39.80 ±4.72	26.6	27.6 ±4.49	36.3	0.992 ±0.008	0.982 ±0.018
Steele/seedling	19	22.9 ±0.65	12.1	42.55 ±2.42	24.1	22.5 ±1.63	30.7	0.933 ±0.032	0.934 ±0.031
All material	99	24.5 ±0.41	16.3	49.17 ±1.57	31.6	28.7 ±1.23	42.5	0.890 ±0.021	0.902 ±0.019
All material except Tolman	91	24.4 ±0.49	18.8	48.55 ±1.66	32.5	28.2 ±1.28	43.1	0.910 ±0.018	0.921 ±0.016

of the stock and scion. The trunk circumference measurements of all trees had been taken the previous winter. A summary of the data obtained is shown in Table I. With the exception of Steele on Tolman interstocks, these trees show a high correlation between trunk circumference and weight of tops. The only apparent explanation for the low correlation of trees on Tolman interstocks is that since these trees are much less variable than the other groups, the small changes in trunk circumference are not associated with similar changes in total weight. When all the trees are grouped together, a value of .89 ± .021 for the coefficient of correlation between trunk circumference and weight of tops is obtained, and when the Tolman trees in the first planting are excluded, this value is increased to .910 ± .018. In order to determine whether the area of trunk cross section might give a closer relationship to the weight of the tree than trunk circumference, correlations were also run between these two sets of data. However, any such increase in the correlation coefficient was so slight as to be unimportant.

Since the real value of these results would be in their use in obtaining accurate estimates of the weight of the tree top, a comparison was made of actual and calculated tree weights as presented in Table II. Calculated tree weights were obtained from trunk circumference, using a regression equation based on the correlation coefficient obtained by correlating the trunk circumference with actual weights. These calculated weights show errors of 4 per cent to 13 per cent except in the case of Steele/Northern Spy/seedling trees, in which case the average error amounts to 27.9 per cent. However, when individual trees are considered, it is noticed that there is an even greater error in these computed figures. Thus in the case of Steele/seedling trees—1st P, these errors range from 0.2 per cent to 60.2 per cent, though by computation from the standard deviation 95 per cent of these cases would have an error of less than 27 per cent. When all the trees are grouped together, the average error of estimate is 15.7 per cent. The area of trunk cross section was also used to estimate the weight of the tree top. While the error was a little less (9.75 per cent as against 10.3 per cent) in the case of Steele/seedling trees, such a reduction in error is again too slight for the extra work involved.

TABLE II—Error (Per Cent) of Calculated Weights

Group	No. of Trees	Error (Per Cent)	Cv Error
First Planting			
Steele/N.Spy/seedling	7	27.9±11.1	93.8
Steele/Tolman/seedling	8	25.4±8.95	93.3
Steele/seedling	35	10.3±2.10	118.9
Second Planting			
Steele/Fameuse/seedling	13	12.1±3.28	93.9
Steele/Tolman/seedling	11	13.6±3.02	70.2
Steele/W. River/seedling	6	4.1±1.75	96.6
Steele/seedling	19	9.8±1.35	59.0
All material	99	14.9±1.49	95.1
All material except Tolman	91	15.7±1.54	97.6

While it is sometimes disconcerting to have such large individual errors between the actual and the estimated weights, it should not be forgotten that such errors may often point to some factor modifying the relationship between trunk circumference and weight of tops which might otherwise pass unnoticed. Factors which might tend to produce a large trunk and small tree (by weight) are: pruning; blossom formation and fruiting; frost injury; winter injury; and dwarfing of the tree by (a) rootstock; (b) sandy soil; and (c) root injury by tools, insects, and so on. On the other hand, factors which would induce the production of a small trunk and a large tree (by weight) are: invigorating the tree by (a) vigorous stock; and (b) fertile soil.

The data obtained from this analysis confirm the work previously reported on this subject, that there is a close correlation between trunk circumference and weight of tops and that the latter may be estimated with reasonable accuracy by computation from trunk circumference measurements.

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Scion Influence on Nursery Apple Tree Roots[1]

By F. B. LINCOLN, *University of Maryland, College Park, Md.*

THE writer is looking for support of the concept: apple scions usually induce specific dispositions of roots from seedling stocks. The data given in this paper are part of a study in the nursery to determine the compatability or desirability of an assortment of material that might be used for apple stocks when propagated vegetatively. The method of study is to bud the material for trial into domestic apple seedlings from the Northwest and these budlings are subsequently budded with comestible varieties, so that eventually the material being observed becomes an intermediate stock. The observations reported here are of the roots developed under 102 different clones budded into 3-year-old seedlings. It is not customary to use seedlings as old as these, but the year they were purchased there was a scarcity and a "grafting" grade was secured which was neither good straight rooted nor branch-rooted seedlings. For various reasons they did not get into good condition for budding the year that they were lined out in the nursery so it was delayed until the second year, which made the roots 3 years old before they might be influenced by alien tops. The nursery soil in which these roots were grown was a deep, sandy loam with usually sufficient moisture. This study is of interest because of the age of roots budded and the wide assortment of clones used as buds.

The buds represent five groups of material all of which was intended for stocks. There were five groups because there were comestible varieties, hybrids containing spy blood, hybrids containing wild American crabapple blood, hybrids with Asiatic crabapple blood, and native wildings. The comestible varieties used were: Stayman, York, Golden Delicious, Hibernal, Ferman's Paragon, Gilbert's Black Twig, Limbertwig, Spy, Cortland, Yates, Buff, Anoka, Summer King, Summer Queen, July, and Chenango.

A side note is worth mentioning here, in that Spy itself did well on domestic seedlings, but buds of some hybrids having Spy blood gave very poor stands, which might make them objectionable as stocks.

When the budlings were 2 years old and their roots 5 years old, they were carefully dug to determine if there were any definite dispositions of roots associated with their various alien tops. The digging was done in the inclement weather of early winter and the trees had to be reset to continue the compatability study so that at any time very few kinds were out of the ground for study and comparison. Whenever the roots of any combination showed a prevalence of a definite disposition, samples were photographed and these pictures used for record and comparison. Small pictures become mostly two dimentional and do not give the feelings gained from digging the roots or seeing them displayed as several groups on the ground. Out of the 102 kinds grown as budlings only 30 showed root disposition constant enough to be photographed and the 10 best are shown in Fig. 1. Besides roots the

[1]Scientific Paper No. A4. Contribution No. 1721 of the Maryland Agricultural Experiment Station (Department of Horticulture).

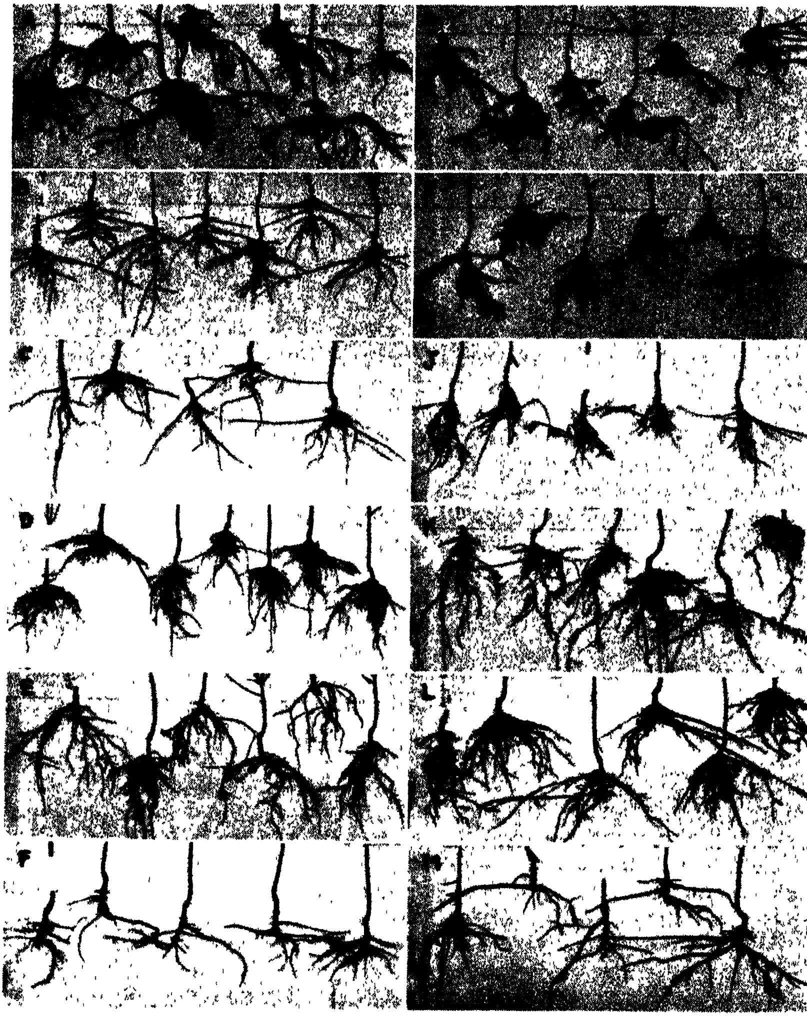

FIG. 1. Domestic seedling roots carrying different tops: A, Seedling/seedling; B, Type XII/seedling; C, Gilbert's Black Twig/seedling; D, Mary's Spreading/seedling; E, Red Astrachan/seedling; F, Spy x Delicious 20–10/seedling; G, Quait Club/seedling; H, Stayman/seedling; J, Limbertwig/seedling; K, Transcendent/seedling; L, Pewaukee x Oldenburg/seedling; and M, Malus No. 9 B.H.S./seedling.

pictures show the amount of seedling stem that went into the composition of the trees. Stems in Fig. 1, G, K, and M show bud shoots with a wide offset to the seedling stem. The writer feels that this behavior is some phase of incompatability. Before observing the root pictures it would be well to consult a diagram of some root features, presented by the writer in another paper in this volume.

Fig. 1, A, is of roots of domestic apple seedlings 5 years old that

have developed under their own tops. There is much similarity in these roots. Notice the arching in some of them. The writer has seen this arching occasionally in other experiments and has felt that it was due to poor transplanting and not a characteristic. This time the arching is only seen in the unworked seedlings and is different than in the roots of G. This feature was not appreciated at digging time when attention was centered on the lack of deep roots that seedlings should have had under such soil and moisture conditions. Fig. 1, B, D, and F show distinctly different roots to each other and to those with seedling tops. One might consider the roots in D, as coming from material that showed burr knots, but the parent tree supplying the buds did not show them. When looking for similarity in roots it was considered worthwhile to picture one set that, in the writer's opinion, did not show conformity. This is pictured in C. Neither do the roots pictured in F show conformity, but they do have a peculiarity and are distinct in the characteristic of being a very small system for the size of the tree. These trees were among the largest in the experiment, and it did not seem possible that they could be supported by such small root systems.

The seedling roots shown in Fig. 1, A, E, and L, are much alike, but on close inspection will be found to differ. The roots of each group are quite consistent within themselves, but just what the differences are is hard to tell, aside from the slope of the lateral roots.

Roots pictured in G, and J, were chosen because of their grotesque characteristics. The peculiar form is obvious in G, but in J it appeared that the lateral roots had been enclosed in cylinders that confined them, while they grew downward. It would be of great value to know that these forms and the others pictured could be repeated in another trial. Such verification is essential, but a long task.

The roots in Fig. 1, H, are likely quite similar to those in Fig. 1, A, only the plants are not so large and the roots probably not so well developed. They are 5-year-old seedling roots that have had Stayman tops the last 2 years. Those with York and Golden Delicious tops were identical to these. Aside from their uniformity they apparently have not been much changed by the alien tops, and are quite different from the roots of self-rooted Stayman and York trees.

The roots in Fig. 1, K, show very dominant vertical development from the distal end of the original seedling roots and are quite different than those in A, which carried their seedling tops for all 5 years. Fig. 1, M, is of roots under buds of a wild American crabapple or a hybrid of it. Domestic apple roots developed under this group are quite likely to be very coarse, but lack the strong tap root development usually found on seedling of the wild American crabs.

The data of this experiment show that 3-year-old domestic apple seedlings may be made to change their root characteristics where other tops are grafted on to them, but the ability of these alien tops to induce changes in the roots of nursery trees is not prevalent for in this study where 102 different clones were used, only 30 produced roots that were uniform enough in disposition or had other peculiarities sufficient to attract attention. In some of the cases of marked uniformity of roots, they were not noticeably different in disposition from those of the ungrafted seedlings.

Evidence of Scion Influence on Stock[1]

By F. B. Lincoln, *University of Maryland, College Park, Md.*

IN THE stock-scion relationship the writer has been interested with the roots and their development, for it is the objective to have a very definite root system to place under a tree, to contact and explore its soil. The root-system is a growing and developing organization and is composed of two portions for consideration: the frame or gross structure, and the absorbing area which is roughly the distal few inches. Perhaps the former is a surviving remnant of the latter or it may have means of its own to expand. A developing root system has components existing in three states: active, surviving, and atrofying. The writer considers only the strong active component for it will be the remaining one in the subsequent system as extention and development continues. Yet, the surviving and atrofying components may be just as characteristic of inate tendencies having expression prior to the time of observation. The writer views the root or stock generally as a positive acting reproducible thing determining its own formal disposition rather than a pliant batch of tissues awaiting external influences to give it form. Thus, it has inherent tendencies for development and functioning. Even though the origin of roots is adventitious it does not necessitate that they do not cohere to a pattern as they develop, which will be duplicated when the nature of stocks is the same and is unrestricted by the soil.

In conflict with this view are some American observations showing that the scion influence is the decisive agent in determining the formal characteristics of apple tree roots. From the reports, one would gain that this influence is prevalent when the roots are French Crab seedlings. This is not a recent thought, for in 1904 Beach and his associates at the Experiment Station at Geneva, New York, were able to classify varieties of apple trees according to character of the grafted seedling roots. It is a great loss that this information was not published. From the published observations in America, one would surmise that the roots of grafted apple trees have specific forms of disposition induced by the scion varieties and that this situation is prevalent for the observations are all positive and the idea has not been refuted. It should be noted that the young trees observed were root grafted on French Crab seedlings and include not over 30 varieties of scions which were selected possibly with the knowledge that they had shown this peculiar behavior in nurseries. The idea is intriguing that roots of apple trees are controlled specifically in number and disposition in the soil by the part or parts above ground. The important information is the prevalence of this behavior.

For an appreciation of stock-scion relations to root development, it should be determined whether the formal characteristics of root systems of grafted apple trees are the expression of inate tendencies of the root for development or are induced by directing principles

[1]Scientific Contribution No. 529, Department of Horticulture, Maryland Agricultural Experiment Station.

from remote parts of the tree. Both must be known before the effect could be thought of as a resultant of them, as a blend. The situation might be clarified if it was made definite when in the formal development of a root system it is to be observed and considered. The writer has an objective for a mature root system, but only juvenile ones are easily produced and observed and have been effected experimentally. It is not known that roots become more characteristic with age. Surely some arbitrary point must be set in the formal development of a root system for discussion and reference. If the process of development is to be considered more than one point will be necessary. The writer has wished several times that he could have seen how a particular lot of roots looked two years before and how they would appear in another two years. It would be ideal if the same root material could be of several different ages when the observation was made to give a better idea of the tendency. The soil environment in these investigations should in no way hinder the free growth and development of the roots.

Some years ago there was a real opportunity to see the influence of the scion on the root form of root grafted trees in a commercial nursery. It was a year when seedling stock was scarce and many small seedlings were used. At this nursery, the bench grafts had root pieces usually smaller in diameter than the scions. They grew into good plants and by fall the roots were at least 25 times the weight of the original piece, all having developed under alien tops. The stocks were not French Crab but the seed was of European origin. Permission was obtained to dig several trees each of 10 random varieties to see the differences in their root systems. When these were assembled for comparison there was no marked relative difference in the roots of all 10 varieties. The disappointment was so great that it cannot be recalled what the top varieties were. Certainly anything as common as this scion influence is suspected of being should have been easily found in this material. Perhaps these varieties induced the development of the same type of root system so no difference was observed.

Three years ago, E. A. Seigler had over a hundred French Crab seedlings sent to him by a nurseryman thinking that they showed "noninfectious hairy root", but they did not. Their large number of lateral roots appealed to the writer as experimental material. The objective was to see which and how many of these laterals would continue to grow and the disposition they would develop under some selected scions. To prevent an undue amount of wound stimulus that would accompany root grafting, it was decided better to supply the tops by budding the following summer. There may be objection raised to budding this material to produce the effects desired, for root grafting is supposedly preferred, but the writer has occasionally found obvious cases in 2-year-old budlings. It is not known that the effect will be identical in budding as with root grafting. The buds used were of varieties and clones that had shown conspicuous repetition of similar differences in their roots; when grown at one time either as self-rooted plants or as budlings. The following is a list of the number of buds that grew out of the eight or nine buds set of each: Early McIntosh, 4; Smokehouse, 7; Jonathan, 7; Melba, 9; Jeffries, 7; Terry, 8; P-103,

4; P-111, 7; P-137, 5; P-175, 8; P-197, 5; P-198, 3; P-305, 8. Only those roots are pictured here that showed a tendency toward a consistent individual peculiarity. The plants were grown in a deep loam soil of perfect condition. When the budlings were 2 years old they were dug for observation. The most evident general development was in the direction away from an adjacent row of larger trees. Injuries to root systems by cultivating tools, aphis, and hairy root are very disconcerting in such a study if a large number of the plants are effected.

Some formal root characters are shown in Fig. 1, A. Those shown as 1, 2, 3, and 4 are possible positions for lateral development from the original root piece, which are: 1, a uniform distribution; 2, from the proximal end; 3, from the distal end; and 4, a peculiar formation that has been found. When more than one lateral develops there is a question of their symmetrical distribution. Features of lateral and secondary

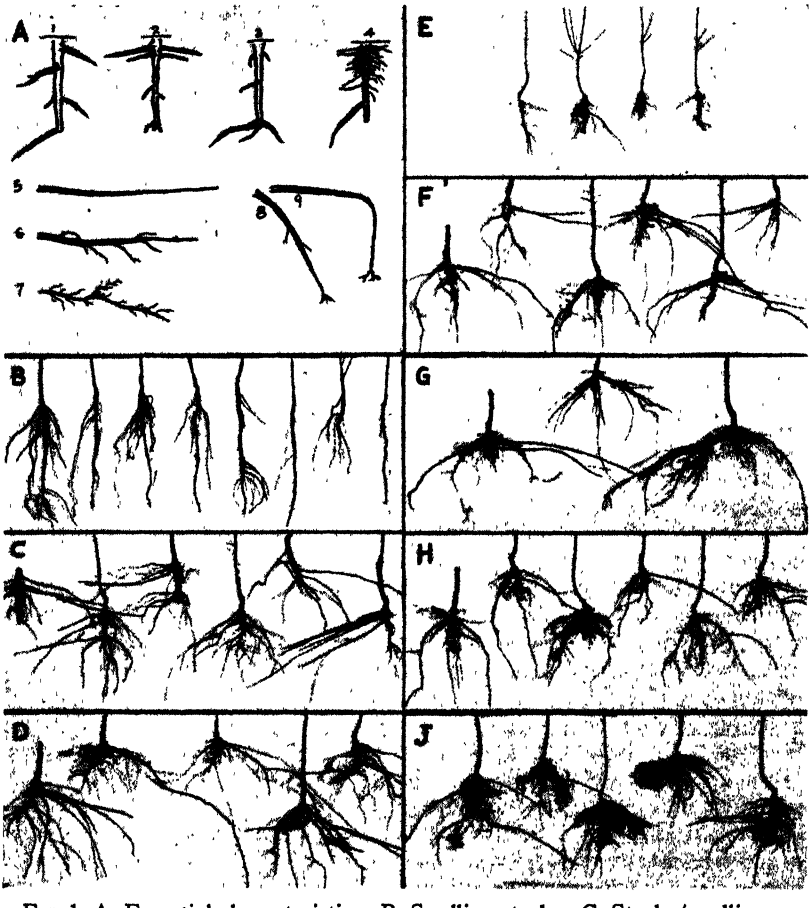

FIG. 1. A, Essential characteristics; B, Seedling stocks; C, Stocks/seedlings; D, Terry/seedlings; E, P-103/seedlings; F, P-315/seedlings; G, P-198/seedlings; H, P-111/seedlings; and J, P-197/seedlings.

lateral roots, are shown by 5, 6, and 7. They may be straight or crooked with more or less absorbing elements attached. Other features worth observing are the degree of terminal dominance for extension and the intervals at which secondary roots occur. The presence of secondary laterals may not be a conspicuous feature in roots of this young material, still the fact, may be that scion influence is more evident in the secondary laterals than in the positions of the primary ones which might be determined by wound stimulus. See roots Fig. 1, C, No. 4 and H, No. 5 for secondary laterals. They are very essential for the complete contact and exploration of the soil. The slope of the laterals is shown in Fig. 1, A, 5, 8, and 9. This and similar discussions have dealt only with the gross root system or frame. There is a probability that marked inherent or induced differences could be found in the roots of the absorbing area of trees growing in an unrestricting soil. By using some scheme as this diagram a root system might be described in a manner as: few, symmetrical, 2–6–9–14.

Some of the original seedling stocks used may be seen in Fig. 1, B. Note the number of lateral roots for which they were selected. The main root was shortened before planting but the laterals were undisturbed.

The further development for two years of some of these roots with seedling tops is shown in Fig. 1, C. The tops of these seedlings were cut back to make them more comparable with the budlings. Compare with these, the roots in Fig. 1, D and J, developing under alien tops, and it is possible that the root disposition is more uniform. There is the probability that if the roots in J had grown more they would be identical with those in D. The writer has the habit of frequently placing the tree that appeals to him first in the arrangement. So, in observing these pictures, it might be good to hide the first root system and see what the others are like. The writer wishes to see a marked similarity in four out of every five root systems of a lot to believe that the scion is the determining agent in their formal distribution. The roots of D have one peculiarity in that they are asymmetric, that is, the strongest development is in one direction.

To show scion induced root formal development it is necessary that the roots make sufficient growth. The roots in Fig. 1, E are approximately no larger than they were two years before when the buds were set and so far have the characteristics of the original seedlings. Furthermore, excessive root growth should not be misleading if it is considered that the scale is larger. A different root type is seen in Fig. 1, F and H with the laterals having a greater slope and with much of the original seedling root atrofying. Another form of root system is shown in Fig. 1, G with less slope to the laterals and showing greater width. The soil was a deep moist loam that should have encouraged deep rooting and it might appear that this one did not respond. Even with the original seedling root atrofying and with less slope to the laterals the writer is not sure but these roots are really as deep as the others, having taken a wider course to develop the depth.

While this experiment was not a conspicuous demonstration of scion induced root formal disposition in very young trees, the writer does

agree that certain selected scions may be associated with particular root forms of attached seedling roots. He is also of the belief that budlings influence root disposition as frequently as do grafts. It is not known that the young root will behave the same for a selected top variety when the tree is made by root grafting as it will by budding. The important question is, how prevalent are these varieties that will make a decided difference in young seedling roots? After several years of search for this behavior with hundreds of varieties and clones, the writer believes that it is probable that of any random selection of varieties not over 20 per cent of them will consistently induce a specific characteristic root disposition of young seedling roots.

Similarity in the Nursery of Several Malling Apple Stock-and-Scion Combinations which Differ Widely in the Orchard[1]

By H. B. Tukey and K. D. Brase, *New York State Agricultural Experiment Station, Geneva, N. Y.*

OVER a period of several years in the propagation of apple trees on various Malling clonal rootstocks for orchard planting, the height and diameter of the budlings of various varieties of apples when budded on several clonal rootstocks have been of some interest. Whereas, in the orchard, trees on the Malling IX rootstock, for example, are very dwarf (2) as contrasted with trees on the Malling XII rootstock, the same rootstock-scion combinations show no such marked differences in the nursery. On the contrary, their most striking characteristic is the similarity in height and diameter of budlings among the various combinations of a given variety.

This paper places these facts on record as they concern four varieties of apples on several Malling rootstocks in the nursery, using as an example the data for the season of 1940.

Materials and Methods

From 17 varieties, the McIntosh, Cortland, Delicious and Northern Spy were selected for study. The work was conducted on the Station grounds on Ontario stony loam, a soil of high fertility, and regularly used by the nursery industry for fruit tree production. All rootstocks were propagated on the Station grounds and all budding was done under the direct supervision of the junior author.

From several grades of rootstocks planted, only well rooted plants of two of them were included in this study, namely, the extra (1/4 inch and above in diameter) and No. 1 grades (3/16 to 1/4 inch in diameter).

The growth of the rootstocks and of the budlings was equal or superior to adjacent commercial blocks of nursery stock. There were from 50 to 500 individuals in each rootstock-scion combination, mostly in the neighborhood of 200. Because of the general uniformity of the material it was unnecessary to measure more than 20 individuals of each combination. Measurements of height were taken from the union, and measurements of diameter were made 2 inches above the union.

Results

None of the combinations showed evidences of incompatibility in the nursery row, the height of the budlings for a given scion variety presenting a remarkably uniform appearance. This was in part due to the fact that the tallest scions in all combinations reached about the same height and tended to hide the smaller individuals in the groups. Closer examination showed this apparent uniformity in height to be

[1]Journal Article No. 452 of the N. Y. State Agricultural Experiment Station.

less striking than it at first seemed, and yet the measurements in Table I indicate close similarity.

TABLE I—HEIGHT AND DIAMETER OF BUDLINGS OF FOUR VARIETIES OF APPLES ON MALLING ROOTSTOCKS IN THE NURSERY

Malling Rootstocks	I	II	III	IV	V	VII	IX	XII	XIII	XVI
					McIntosh					
Height (Cm)	109.9	120.6	119.9	116.6	116.1	117.1	—	111.8	114.6	110.2
Diameter (Mm)......	10.7	11.4	10.5	11.5	10.6	9.8	—	10.0	11.3	11.1
					Cortland					
Height (Cm).........	112.3	120.9	109.5	116.3	113.5	108.2	—	105.9	116.3	120.6
Diameter (Mm)......	10.2	10.1	9.8	10.6	9.3	9.8	—	9.4	11.4	10.8
					Delicious					
Height (Cm).........	122.4	112.8	10.92	115.1	116.3	112.8	94.0	138.7	125.5	117.3
Diameter (Mm)......	10.7	11.5	10.2	11.5	11.0	11.4	9.6	12.9	11.9	12.0
					Northern Spy					
Height (Cm).........	120.9	103.6	116.6	118.6	—	113.3	101.8	—	—	—
Diameter (Mm)......	12.1	11.7	12.0	12.3	—	11.2	12.2	—	—	—

The McIntosh variety, in particular, made much the same growth on all nine rootstocks, although two of them (XII and XVI) produced standard trees in the orchard, and two others (IV and VII) produced dwarfish trees, while the other rootstocks (I, II, III, V, and XIII) produced trees of varying intermediate sizes.

There was some tendency for the most dwarfing rootstocks to produce the smallest budlings; that is, the smallest trees are those of Delicious and Northern Spy on the Malling IX rootstock, which produces the most dwarf tree in the orchard. Yet the heights of 94 centimeters and 101.8 centimeters which they attained respectively, are not especially small and nowhere near as relatively small as is the case with these same combinations after a few years of growth in the orchard (1). In short, the effect of the rootstock upon the scion, insofar as height and diameter of budling is concerned, and involving no incompatible combinations, has been very slight and of much less magnitude in the nursery than in subsequent years in the orchard.

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The Performance of Malling Apple Rootstocks in the Nursery as Regards Stand of Lining-out Stock and Production of Nursery Trees[1]

By H. B. TUKEY and K. D. BRASE, *New York State Agricultural Experiment Station, Geneva, N. Y.*

BECAUSE of the general interest in the Malling rootstocks for fruit trees, it is of importance to appraise their performance from various angles. In previous publications their adaptability to climatic conditions of western New York (3), methods of propagation (2), yield of rooted plants from layers and cuttings (4), and resultant stand as lining-out stock (5, 6) have been considered. This paper records additional information as to the behavior of certain of the unworked Malling rootstocks as lining-out stock, what stands and sizes of trees have been produced by them in the nursery, and how these have behaved in a general comparison with seedling rootstocks.

MATERIALS AND METHODS

The Malling rootstocks used were propagated on the Station grounds at Geneva, New York, both from layers and from hard wood cuttings and were graded into the usual commercial grades of Extra (1/4 inch in diameter at the collar, and up), No. 1 (3/16 to 1/4 inch), No. 2 (2/16 to 3/16 inch), and No. 3 (below 2/16 inch). In addition they were graded for their comparative root development as "well-rooted", "medium-rooted", and "poorly-rooted". The imported French Crab seedlings were from France and from Holland, and the domestic French Crab seedlings were from commercial firms in Connecticut, Kansas, and Pennsylvania. In addition one lot of French Crab seedlings was raised on the Station grounds at Geneva from seed brought from France. The imported French Crab seedlings, those secured from Pennsylvania, and those grown at Geneva, were of the branch-root type as contrasted with the straight-root type from Kansas. One lot from Connecticut was grown by the 2-year method (1).

The soil is classified as Ontario stony loam. It is of high fertility and is considered to be a good commercial nursery soil. Observations are presented of material lined out during the seasons of 1928, 1938, 1939, and 1940. The nursery trees were propagated by budding on the Station grounds.

RESULTS AND DISCUSSION

The growth and performance of both the unworked rootstocks and of the nursery trees were equal or superior to those of good blocks of commercial nursery stock grown in the immediate vicinity. In the accompanying tables there are enumerated the several rootstocks used, their grades, the number in each lot which was budded, and the number of 1-year-old and 2-year-old trees which was produced from each. The records are self-explanatory excepting possibly for the record of the

[1]Journal article No. 455 of the New York State Agricultural Experiment Station.

TABLE I—STAND OF MALLING ROOTSTOCKS AS LINING-OUT STOCK IN THE NURSERY (LINED OUT SPRING, 1938)

Malling Types	Size and Rooting Grades*	Number Lined Out	Rootstocks Budded		One-Year Trees		Two-Year Trees	
			Number (Stand)	Per Cent of Those Lined Out	Number	Per Cent of Rootstocks Budded	Number	Per Cent of Rootstocks Budded
I	Extra w. r.	900	697	77.4	596	85.5	574	82.3
I	No. 1 w. r.	100	95	95.0	87	91.5	87	91.5
III	No. 1 w. r.	183	174	95.0	151	86.7	149	85.6
IV	No. 1 w. r.	100	80	80.0	72	90.0	71	88.7
VII	No. 1 w. r.	100	100	100.0	87	87.0	87	87.0
IX	No. 1 trans.	700	560	80.0	528	94.2	516	92.1
IX	No. 1 p. r.	300	257	88.6	195	75.8	190	73.9
XII	No. 1 w. r.	1680	1446	86.0	1358	93.9	1314	90.8
XII	No. 2 w. r.	440	193	43.8	147	76.1	117	60.6
XIII	Extra w. r.	1030	930	90.2	826	88.8	814	87.5
XIII	No. 1 w. r.	1140	1095	96.2	1033	94.3	966	88.2
XVI	No. 1 w. r.	850	750	88.2	699	93.2	680	90.6

*Grades—Extra = 1/4 inch in diameter at the collar, and up
No. 1 = 3/16 to 1/4 inch
No. 2 = 2/16 to 3/16 inch
No. 3 = 1/16 to 2/16 inch
w. r. = well-rooted
p. r. = poorly-rooted
trans. = transplanted

numbers of rootstocks which were budded out of those which were lined out. This number is used as a practical measure of the "stand" of the rootstocks rather than a count of all rootstocks which were living, for the reason that unless a rootstock has made sufficient growth to receive a bud it cannot be considered from the standpoint of successful nursery practice to be a satisfactory or "surviving" individual.

Differences Between the Various Malling Clones:—The tables show clearly that the resultant stands vary when the several Malling clones are used as lining-out stock. In a season of normal spring rainfall (April 3.11 inches, May 3.55 inches) as that of 1940, these differences are not so apparent, but in a season of deficient rainfall (April 2.40 inches, May 1.09 inches) as that of 1939, they become more pronounced. Table II shows that when comparisons are made of the same grades of materials, namely, the well-rooted No. 1 grade, except where otherwise noted, the percentage stand is as follows: I, 98.6; II, 72.1 ("medium-rooted" grade); III, 89.6; IV, 94.0; V, 72.2 ("extra" grade); VI, 93.0; VII, 96.2; IX, 96.5; XII, 60.8; XIII, 92.9; and XVI, 93.9. The clones which gave the best stand as lining-out stock were those which rooted most easily in the stool blocks, namely, I, IV, VII, IX, XIII, and XVI, whereas the clones which gave the poorest stands were those which rooted with greatest difficulty in the stool blocks, namely II and XII (4, 6).

Comparison of Malling Clonal Rootstocks with French Crab Seedlings as Lining-out Stock:—Table IV gives the record of French Crab seedlings planted in 1928, and which may be compared with the data for Malling clonal material in the preceding tables. The 83 to 88 per

TABLE II—STAND OF MALLING ROOTSTOCKS AS LINING-OUT STOCK IN THE NURSERY (LINED OUT SPRING, 1939)

Malling Types	Size and Rooting Grades*	Number Lined Out	Rootstocks Budded		One-Year Trees	
			Number (Stand)	Per Cent of Those Lined Out	Number	Per Cent of Rootstocks Budded
I	Etxra w. r.	430	417	96.9	377	83.2
I	Extra p. r.	150	140	93.3	132	93.5
I	No. 1 w. r.	579	571	98.6	499	87.3
I	No. 1 p. r.	926	873	94.2	735	84.1
I	No. 2 w. r.	422	381	90.2	320	93.9
I	No. 2 r. c.	146	140	95.8	134	95.7
II	No. 1 m. r.	187	135	72.1	95	70.3
II	No. 1 p. r.	234	176	75.2	125	71.0
III	Extra w. r.	68	61	89.7	38	62.3
III	No. 1 w. r.	231	207	89.6	193	93.2
IV	Extra w. r.	48	48	100.0	40	83.3
IV	No. 1 w. r.	354	333	94.0	277	83.1
V	Extra w. r.	83	60	72.2	57	95.0
V	Extra p. r.	34	25	73.5	21	84.0
V	No. 2 w. r.	42	36	85.7	26	72.2
VI	No. 1 w. r.	43	40	93.0	31	77.5
VII	Extra w. r.	158	143	90.5	119	83.2
VII	No. 1 w. r.	264	254	96.2	219	86.2
VII	No. 1 m. r.	141	135	95.7	112	82.9
VII	No. 2 w. r.	380	372	97.8	327	87.9
VII	No. 3 w. r.	89	86	96.6	75	87.2
IX	Extra w. r.	190	175	92.1	127	72.5
IX	No. 1 w. r.	637	615	96.5	555	90.2
IX	No. 1 p. r.	285	121	42.4	91	75.2
IX	No. 2 m. r.	277	140	50.5	122	87.1
IX	No. 2 p. r.	267	93	34.8	64	68.8
IX	No. 2 r. c.	200	140	70.0	125	89.2
XII	Extra w. r.	261	172	65.9	96	55.8
XII	No. 1 w. r.	360	219	60.8	156	71.2
XII	No. 1 m. r.	684	316	46.1	206	65.1
XII	No. 1 p. r.	350	214	61.1	155	72.4
XII	No. 2 w. r.	132	119	90.1	99	83.1
XII	No. 2 m. r.	197	140	71.0	100	71.4
XII	No. 2 p. r.	271	195	71.9	156	80.0
XIII	Extra w. r.	904	745	82.4	641	86.0
XIII	Extra m. r.	369	268	72.6	209	77.9
XIII	Extra p. r.	400	213	53.2	184	86.3
XIII	No. 1 w. r.	355	330	92.6	274	83.0
XIII	No. 1 p. r.	213	191	89.6	167	87.4
XIII	No. 2 p. r.	100	76	76.0	70	92.1
XVI	Extra w. r.	356	332	93.2	294	88.5
XVI	No. 1 w. r.	133	125	93.9	110	88.0
XVI	No. 1 m. r.	200	120	60.0	106	88.3
XVI	No. 1 p. r.	176	128	72.7	91	71.1

*Grade—Extra = 1/4 inch in diameter at the collar, and up
No. 1 = 3/16 to 1/4 inch
No. 2 = 2/16 to 3/16 inch
No. 3 = 1/16 to 2/16 inch

w. r. = well-rooted
m. r. = medium-rooted
p. r. = poorly-rooted
r. c. = rooted cuttings

cent stands of imported French Crab seedlings would be considered as good but not outstanding in commercial nursery circles. The Connecticut-grown seedlings gave an exceptionally high stand, 97 to 99 per cent, and the Geneva-grown material was low, 55 to 80 per cent. The straight-rooted lot from Kansas was distinctly inferior; this has been the usual experience with straight-root apple seedlings in western New York nurseries over a period of years (1).

The stands of Malling rootstocks consistently equal or surpass those for French Crab seedling rootstocks, the values ranging from 71 to 100 per cent for material of comparable grade and with most of the figures 90 per cent or above. While this is a definite superiority it is a question whether under the best commercial nursery practices it is of itself sufficient to justify the commercial use of the Malling root-

TABLE III—STAND OF MALLING ROOTSTOCKS AS LINING-OUT STOCK IN THE NURSERY (LINED OUT SPRING, 1940)

Malling Types	Size and Rooting Grades*	Number Lined Out	Number Budded (Stand)	Per Cent Budded
I	Extra w. r.	1030	1013	98.3
II	Extra m. r.	100	82	82.0
II	No. 1 w. r.	47	42	89.3
II	No. 2 w. r.	88	80	90.9
II	No. 3 w. r.	32	32	100.0
III	Extra w. r.	75	75	100.0
III	No. 1 w. r.	255	251	98.5
III	No. 2 p. r.	75	65	86.6
IV	No. 1 w. r.	300	300	100.0
IV	No. 1 p. r.	52	48	92.3
IV	No. 2 w. r.	75	75	100.0
IV	No. 3 w. r.	100	96	96.0
V	Extra w. r.	30	30	100.0
V	No. 1 w. r.	32	31	96.8
V	No. 2 w. r.	35	35	100.0
V	No. 3 w. r.	33	27	81.8
VII	No. 1 w. r.	515	514	99.8
VII	No. 2 w. r.	200	189	94.5
VII	No. 3 w. r.	100	95	95.0
VII	No. 1 p. r.	220	194	88.1
IX	Extra w. r.	740	717	96.8
XII	Extra w. r.	255	251	98.4
XII	No. 1 w. r.	393	382	97.4
XII	No. 2 w. r.	274	266	97.0
XII	No. 3 w. r.	87	76	87.3
XIII	Extra w. r.	1030	1013	98.3
XVI	Extra w. r.	180	179	99.4
XVI	No. 1 w. r.	500	494	98.8
XVI	No. 2 w. r.	250	243	97.2
XVI	No. 3 w. r.	95	90	94.7

*Grade—Extra = 1/4 inch in diameter at the collar, and up
No. 1 = 3/16 to 1/4 inch
No. 2 = 2/16 to 3/16 inch
No. 3 = 1/16 to 2/16 inch
w. r. = well-rooted
m. r. = medium-rooted
p. r. = poorly-rooted

stocks. It is possible, however, that in some seasons, especially in those which are unfavorable to securing a good stand of lining-out stock, as in a spring of deficient rainfall, the stand of Malling rootstocks might be commercially superior. It is probable that the improved stand of the Malling rootstocks as a class is due to their general ability to regenerate

TABLE IV—STAND OF FRENCH CRAB SEEDLINGS IN THE NURSERY — TABULATION OF SEEDLINGS SET IN 1928, CARRIED THROUGH 1930 SEASON

Source of Seedlings†	Size Grades*	Number Lined Out	Rootstocks Budded		Two-Year Trees	
			Number	Per Cent of Those Lined Out	Number	Per Cent of Rootstocks Budded
France	No. 1	500	439	87.8	412	92.8
Holland	No. 1	600	498	82.6	432	86.7
Connecticut transplant	Extra	250	249	99.6	226	90.7
Connecticut	No. 1	250	244	97.6	218	89.3
Kansas	No. 1	250	123	49.2	113	91.8
Pennsylvania	No. 1	250	235	94.0	208	88.5
Geneva	Extra	250	138	55.2	110	79.7
Geneva	No. 1	250	171	68.5	145	84.8
Geneva	No. 2	250	199	79.6	177	88.9
Geneva	No. 3	250	150	60.0	137	91.3

*Grades—Extra = 1/4 inch in diameter at the collar, and up
No. 1 = 3/16 to 1/4 inch
No. 2 = 2/16 to 3/16 inch
No. 3 = 1/16 to 2/16 inch
†The text should be consulted for the descriptions.

roots more rapidly, as contrasted with the slower root regeneration of French Crab seedling rootstocks. The superior stands of the more readily rooting Malling rootstocks, as I, IV, VII, and XIII, as contrasted with the poorer stands of the more difficultly rooting II and XII, support this suggestion.

There seem to be no differences in either percentage or size of 1-year-old and 2-year-old trees produced on Malling clonal rootstocks and on French Crab seedling rootstocks of similar grade.

Relation of Size of Rootstock and Degree of Rooting:—Although all four size grades of lining-out stock gave commercially satisfactory stands, there were some minor differences. For example, the largest grade (Extra — 1/4 inch and up), gave lower stands two seasons out of three than did the No. 1 (3/16 to 1/4 inch) and No. 2 (2/16 to 3/16 inch) grades. The highest stand was consistently with the No. 1 grade (3/16 to 1/4 inch), which is ordinarily recognized as the most desirable by commercial nurseries. The No. 2 grade (2/16 to 3/16 inch) resulted in nearly as good a stand. The No. 3 grade (below 2/16 inch) produced as good a percentage if measured in terms of the unworked individuals which merely grew, but gave in effect a lower stand if measured in terms of individuals which attained a size suffi-

TABLE V—NUMBER OF SEASONS THE INDICATED STOCK AND SCION COMBINATIONS HAVE BEEN MADE — ALL COMBINATIONS SUBSEQUENTLY GROWN TO 2-YEAR-OLD NURSERY SIZE

Variety	Malling Rootstock Types										
	I	II	III	IV	V	VI	VII	IX	XII	XIII	XVI
Baldwin	9	3	3	3	3	3	6	9	8	8	4
Cortland	4	2	3	3	2	1	3	4	4	4	4
Cox Orange	—	1	1	1	—	1	—	2	—	—	—
Delicious	10	5	6	6	5	4	7	7	9	10	6
Early McIntosh	1	1	1	1	1	1	2	3	1	3	1
Fameuse	1	—	—	—	—	—	—	—	—	—	—
Gallia	5–weak	—	—	—	—	—	2–weak	1–weak	4	4	3
Golden Delicious	3	2	—	—	—	—	1	2	—	1	—
Gravenstein	—	1	—	—	—	—	2	1	—	1	—
Grimes	1	—	—	—	—	—	1	2	1	—	—
Jonathan	1	—	—	—	—	—	1	1	1	1	—
Kendall	2	—	—	2	1	1	2	1	3	2	2
Lodi	1	—	—	—	—	—	1	—	1	1	—
Macoun	1	1	—	2	—	—	1	1	2	2	1
McIntosh	10	5	6	6	6	5	5	6	9	10	7
Medina	—	—	—	—	—	—	—	—	—	2	—
Melba	—	—	—	—	—	—	—	—	1	1	1
Milton	1	—	—	—	—	—	—	2	—	1	—
Northern Spy	6	4	4	5	1	—	3	6	4	4	2
Oldenburg	—	—	—	—	—	—	—	1–weak	—	1	—
Red Astrachan	—	—	—	—	—	—	2	1	—	—	1
Red Spy	1	—	—	—	—	—	—	1	—	—	—
R. I. Greening	5	—	2	1	1	—	1	2	5	6	2
Rome	2	1	2	2	1	—	1	1	2	4	1
Roxbury Russet	1	—	—	—	—	—	—	1–weak	—	1	—
Stark	1	—	—	—	—	—	—	1	—	—	—
Starking	1	—	—	—	—	—	—	—	—	—	—
Stayman	1	—	—	—	—	—	—	—	—	—	—
Tompkins King	—	—	—	—	—	—	—	1	—	1	—
Turley	2	1	1	2	—	—	2	2	2	3	1
Twenty Ounce	—	—	—	—	—	—	—	—	—	1	—
Wagener	—	—	—	—	—	—	—	1	—	—	—
Wealthy	2	—	—	—	—	—	2	—	3	3	2
Webster	—	—	—	—	—	—	—	1	—	—	—
Winesap	1	—	—	—	—	—	—	1	—	—	—
Wolf River	—	—	—	—	—	—	—	1	—	—	—
Yellow Newtown	1	—	—	—	—	—	—	1	—	1	—
Yellow Transparent	—	—	—	—	—	—	—	—	—	—	1

cient to be budded and hence to develop into nursery trees. A fair illustration is given with the Malling VII rootstock in Table II, where the Extra grade gave 90.5 per cent stand, the No. 1 grade 96.2 per cent, the No. 2 grade 97.8 per cent, and the No. 3 grade 96.6 per cent. Likewise in Table III, the stand of Malling II is: Extra grade, 82.0 per cent; No. 1, 89.3 per cent; No. 2, 90.9 per cent; and No. 3, 100.0 per cent.

As might be expected there is a direct relationship between the degree of rooting and the resultant stand of lining-out stock. The greatest percentage stands were secured consistently with the best-rooted grades, and the poorest stands with the poorest-rooted grades. For example, with "well-rooted", "medium-rooted", and "poorly-rooted" unworked Malling XIII rootstocks, all of the "extra" size grade, the percentage stands were respectively, 82.4, 72.6, and 53.2 (Table II).

Comparing the factors both of size grade and rooting grade, the conclusion seems warranted that with rootstocks of the type considered usable by the commercial nursery industry, it is more important that the rootstocks be well-rooted than that they be of a particularly large size. Small, well-rooted material is much superior to large poorly-rooted material.

Adaptability of Malling Clones to Various Apple Varieties:—The Malling clones employed have shown congeniality in the nursery with a wide assortment of the more common cultivated varieties of apples. In general they seem to be as successful in accepting buds of apple varieties and in serving as rootstocks for trees in the nursery as are the most favorable seedling rootstock materials now in use in commercial nurseries.

A total of 38 varieties have been tried, though not all with the same rootstocks. All combinations have been successful in the nursery and have produced 2-year-old nursery trees, though not always strong-growing trees. Some combinations have been repeated annually over a period of 10 years. Table V lists the several combinations, indicates those few which have been inclined to produce weak trees, and gives the number of different seasons in which they have been made. In all instances the trees have been successfully grown to 2-year size. Their performance as older trees is not a part of this study, and no attempt is made in this paper to predict such behavior.

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A Comparison on Rooting Induced by Acid- and by Amide Growth Substances[1]

By V. T. Stoutemyer, *U. S. Department of Agriculture, Glenn Dale, Md.*

IN a previous report by the author (4), the rooting responses of plants treated with naphthalene acetic acid were compared with those of plants to which naphthyl acetamide was applied. Cuttings of some plants rooted better with the free acid, but others rooted better when the amide was used. With a few plants, rooting responses were about the same with both compounds. These results suggested that failure to achieve satisfactory results with growth substances on a certain plant may be due to the use of a form less suitable for that particular subject. To determine whether the same differences could be demonstrated with the corresponding indole compounds the similar experiment now reported, comparing indole acetic acid and indole acetamide, was conducted. These compounds were used in talc dust mixtures prepared and applied to the cuttings according to a procedure described previously (3). Since indole butyramide was not available, no comparisons could be made with indole butyric acid.

The results of the tests made with indole acetic acid and indole acetamide are shown in Table I. The talc mixtures used in this experiment contained one milligram of growth substance per gram of talc. The tests were made in a propagating greenhouse in which a temperature of about 70 degrees F was maintained in the sand rooting medium.

The cuttings were classified by arbitrarily determined limits according to the heaviness of the root systems. "Light" rooting describes those cuttings with only a few long roots or with very short roots. "Medium" rooting describes those with an average root system of a desirable type. "Heavy" rooting describes those cuttings which have a much stronger root system than normal.

The results shown in Table I indicate that the variations of response obtained by the use of indole compounds were of the same nature as those obtained with naphthalene compounds. The differences are consistent, since a plant which responded best to a particular form of naphthalene growth substance likewise produces the best rooting when treated with the corresponding indole form. For instance, the naphthalene acetic acid was previously shown (4) to be preferable with Coriaria, Forsythia and Weigela. In these same subjects the better rooting was produced through the application of indole acetic acid. Likewise, the indole acetamide produced superior rooting on plants which root better with naphthyl acetamide, including *Pachysandra terminalis* Sieb. & Zucc., *Skimmia japonica* Thunb., *Melastoma* sp. and others. With some other plants such as *Oncoba Routledgei* Sprague and

[1]Report of cooperative research between the Hillculture Division, Soil Conservation Service and the Division of Plant Exploration and Introduction, Bureau of Plant Industry, United States Department of Agriculture, on methods of vegetative propagation of superior selections of erosion-resistant plants. Thanks are due to the head of the Division, Mr. S. B. Detwiler, for supplying materials and to Mr. F. L. O'Rourke and Mr. Donald P. Dreisbach for assistance.

TABLE I—ROOT FORMATION IN CUTTINGS TREATED WITH INDOLE ACETIC ACID AND INDOLE ACETAMIDE

Treatment	Talc				Indole Acetic Acid				Indole Acetamide			
	Per Cent Rooted				Per Cent Rooted				Per Cent Rooted			
Subject	Total	Heavy	Medium	Light	Total	Heavy	Medium	Light	Total	Heavy	Medium	Light
Buddleia sp. Dec 27 to Jan 6	85	—	25	60	95	45	30	20	10	—	—	10
Buddleia sp. Jan 23 to Feb 3	55	—	12.5	42.5	72.5	—	25	47.5	15	—	—	15
Coriaria sp. Dec 27 to Jan 13	60	—	20	40	80	20	40	20	80	5	35	40
Eupatorium ligustrinum DC. Dec 27 to Jan 18	6	—	6	—	66	6	27	33	72	—	39	33
Forsythia viridissima koreana Rehd. Sep 27 to Oct 22	82.5	—	35	47.5	100	35	57.5	7.5	60	—	2.5	57.5
Leycesteria formosa Wall. Dec 14 to Jan 2	40	—	15	25	67	5	29	33	95	14	45	36
Maurandia sp. Dec 14 to Jan 17	40	—	20	20	45	—	10	35	80	—	45	35
Melastoma sp. Dec 27 to Jan 10	80	—	15	65	85	15	40	30	85	25	40	20
Oncoba Routledgei Sprague Dec 14 to Feb 6	5	—	—	5	35	—	20	15	40	—	20	20
Pachysandra terminalis Sieb. and Zucc.	65	—	—	65	60	—	5	55	97.5	2.5	67.5	27.5
Skimmia japonica Thunb. Aug 13 to Sep 4	100	10	70	20	85	5	40	40	100	50	30	20
Skimmia japonica Thunb. P. I. 135524 Aug 13 to Sep 4	85	20	50	15	90	5	65	20	100	35	60	5
Sorbaria tomentosa (Lindl.) Rehd. P. I. 135529 Sep 16 to Oct 10	35	—	2.5	32.5	60	12.5	22.5	25	32.5	2.5	2.5	27.5
Weigela floribunda Sieb. and Zucc. Aldenham Glow Sep 27 to Oct 10	72.5	—	2.5	70	95	7.5	27.5	35	7.5	—	—	7.5

Eupatorium ligustrinum DC., the responses were quite similar with the two classes of compounds. Allowance must be made in a few cases where comparisons would be complicated by the circumstance that a few plants respond much better to a naphthalene growth substance than to one having an indole ring. However, the generalization may be made that a plant responding best to a particular form of an indole growth substance will likewise prefer the corresponding naphthalene compound if the side chain has the same length. The regularity of these differences shows the existence of some fundamental physiological differences between various groups of plants.

In Table I, about a third of the subjects apparently rooted best when treated with acid growth substance, a similar number responded best with the amides and the remainder were indifferent. In a previous report (4), the proportions were similar.

Inhibition of Rooting and Toxicity

The data in Table I show that the rooting of cuttings of Buddleia was inhibited in several trials when the indole acetamide was used at the strength of 1 milligram per gram. When the strength of the growth substance was reduced to one third of this amount, some rooting took place. Indole acetamide also inhibited rooting of cuttings of Weigela and Forsythia measurably. This effect requires some explanation as it is sometimes encountered in using growth substances in amide form. An excessive concentration of one of the acid growth substances invariably produces severe damage at the base of the cutting and frequently its death. With the amide growth substances, however, as the concentration increases beyond the optimal, rooting may be inhibited on cuttings of certain plants with no apparent direct injury to the cuttings. The same occasional inhibition of rooting may follow use of naphthyl acetamide, but in this case the cuttings may not show the slightest trace of external injury and remain in sound condition. Therefore, toxic effects are apt to be less noticeable in using the amide growth substance than when the acid is used. On other plants, however, the amides cause severe burning if used in excessively high concentrations. Inhibition of rooting without apparent external injury is less common with any of the acid growth substances.

Comparison of Various Naphthalene Growth Substances

Several little known related naphthalene compounds were tried. One of these was alpha naphthyl acetyl glycine which is a simple addition product with the amino acid, glycine. This substance has considerable theoretical interest since Skoog and Thimann (2) have recently produced evidence to show that auxins may be held within plant tissues in combination with proteins.

Tests were made of the related compound 1, 2, 3, 4 tetra-hydronaphthyl 6-acetamide, designated hereafter as tetralyl 6-naphthyl acetamide. Naphthyl butyric acid was included for comparison with alpha naphthyl acetic acid. In all cases the substances were used at a concentration of 1 milligram per gram of talc. Mixtures of equal parts of several of the growth substances were used, but the total concentration

remained unchanged. To compare the action of these compounds, two contrasting test subjects were selected. One of these, *Weigela floribunda* Sieb. & Zucc. "Aldenham Glow", roots best with either indole acetic or naphthyl acetic acid. The other, *Pachysandra terminalis,* roots better when the corresponding amides are applied.

RESULTS WITH WEIGELA FLORIBUNDA

All treatments of *Weigela floribunda* were applied on July 12 at the rate of 1 milligram of growth substance per gram of talc. Six replicated lots of 20 cuttings each were used for each treatment and the cuttings were removed on July 25. In addition to grading and counting the cuttings, an analysis of variance was made in order to determine the significance of the differences in the dry weights of the roots produced by various treatments. The results are shown in Table II.

TABLE II—ROOT PRODUCTION OF *Weigela floribunda* VAR. "ALDENHAM GLOW" UNDER VARIOUS TREATMENTS

Treatment†	Per Cent Rooted				Total Dry Weight Roots (Gms)	Total Dry Weight Tops (Gms)	Milligrams of Roots Produced Per Gram of Tops*
	Total	Heavy	Medium	Light			
Talc	84	—	47.5	36.5	1.4	49.3	28
NAA	95	35.8	45.8	13.0	5.9	48.1	143
ANAG	95.8	45	44	6.6	7.3	48.2	151
NBA	90	16.7	47.5	25.8	4.9	45.9	107
KIB	94.2	21.7	57.5	15	5.7	48.6	117
NAD	73.3	—	42.5	30.8	1.9	46.5	41
TNAD	81.7	0.8	47.5	33.4	2.0	49.2	41

*Difference of 39 indicates significance (5 per cent).
Difference of 53 indicates high significance (1 per cent).
†All mixtures of growth substances with talc contained one milligram of growth substance per gram of talc and are designated as follows: Naphthyl acetic acid—NAA, Alpha naphthyl acetyl glycine—ANAG, Naphthyl butyric acid—NBA, Potassium indole butyrate—KIB, Naphthyl acetamide—NAD, Tetralyl Naphthyl 6-acetamide—TNAD.

In this case, the differences between the two free acids, alpha naphthyl acetic acid and alpha naphthyl acetyl glycine were not significant, showing that the action of the two substances was practically the same. However, the differences between the acids and the amides were highly significant. With Weigela both amides were relatively inefficient and in fact the differences between treatments and check were not great enough to be significant. Naphthyl butyric acid usually has been particularly effective in our trials, but on this plant did not appear to be quite as effective as the other acids, although it produced heavier rooting than did either of the amides.

RESULTS WITH PACHYSANDRA TERMINALIS

Cuttings of *Pachysandra terminalis* root much better with indole acetamide or naphthyl acetamide than with the corresponding free acids. Tips of the new growth were placed in sand in the greenhouse under a cheesecloth shade on September 17. All treatments were applied at the rate of 1 milligram of growth substance per gram of talc. Five replicate lots of 20 cuttings each were used for each treatment. The cuttings were removed and counted on October 28 and were dried

at once in an oven. The data on dry weights were also subjected to analysis of variance.

The data shown in Table III indicate that naphthyl acetamide produced significantly heavier rooting than naphthyl acetic acid, with the weight of roots about twice as great. The indole compounds produced a similar response. Naphthyl butyric acid produced unusually heavy rooting with this subject. This circumstance shows that the basis of the difference between these various growth substances does not rest upon any simple distinction between these various compounds as acids or amides. Apparently, a certain space configuration within the compound, possibly linked to the length of the side chain, is the determining factor. Obviously in many cases the effectiveness of a given compound will depend upon whether or not the compound contains an acid or amide group, but only so long as the length of the side chain is held constant. The tetralyl naphthyl 6-acetamide and the alpha naphthyl acetyl glycine did not show the marked differences observed with Weigela. Apparently the mixing of acid and amide growth substances does not offer much hope of solving the problem raised by the different requirements of plants.

TABLE III—ROOT PRODUCTION OF *Pachysandra terminalis* UNDER VARIOUS TREATMENTS

Treatment†	Per Cent Rooted				Total Dry Weight Roots (Gms)	Total Dry Weight Tops (Gms)	Milligrams of Roots Produced Per Gram of Top*
	Total	Heavy	Medium	Light			
Talc	64	—	—	64	0.151	46.7	3
NAA	67	3	25	39	1.015	43.4	34
ANAG	94	19	50	25	2.911	44.3	66
NBA	98	25	61	12	3.625	46.3	78
IB	97	23	49	25	2.889	50.1	58
NAD	98	16	65	17	2.918	46.2	63
TNAD	85	1	30	54	1.429	46.4	31
IAA	70	—	5	65	0.506	50.0	10
IAD	97	20	34	43	2.477	50.4	49
Equal parts NAA+NAD	72	1	16	55	1.052	52.1	20
Equal parts IAA+IAD	81	1	15	65	0.883	58.3	15

*Difference of 25 indicates significance (5 per cent).
Difference of 33 indicates high significance (1 per cent).
†All mixtures of growth substances with talc contained 1 milligram of growth substance per gram of talc and are designated as follows: Naphthyl acetic acid—NAA, Alpha naphthyl acetyl glycine—ANAG, Naphthyl butyric acid—NBA, Indole butyric acid—IB, Naphthyl acetamide—NAD, Tetralyl naphthyl 6-acetamide—TNAD, Indole acetic acid—IAA, Indole acetamide—IAD.

EFFECT OF HIGHER CONCENTRATIONS

Even when the growth substances are applied in concentrations above the optimal, the differences in the action of the various forms are still clearly discernible. When these substances were applied to *Pachysandra terminalis* and *Weigela floribunda* in concentrations of 4 milligrams of growth substance per gram of talc, using replicated trials, the effects were still consistent and the contrasting preferences of the two plants were still evident. Furthermore, increasing the concentration of a relatively ineffective chemical failed to bring it up to the level of activity of a more suitable substance.

Observations on these and other plants indicated that the tetralyl

naphthyl 6-acetamide was the least toxic of the naphthalene growth substances. Alpha naphthyl acetyl glycine was likewise less toxic than the free naphthyl acetic acid when compared on an equal weight basis. With some subjects, naphthyl acetamide produced injuries almost as severe as those produced by naphthyl acetic acid. Mitchell and Stewart (1) noticed some differences in the internal responses produced by these two chemicals in comparative tests and some differences in toxicity are not surprising. Naphthyl butyric acid was the most likely to produce injurious effects, and though highly effective, must be used with great care.

The more complex addition products such as alpha naphthyl acetyl glycine and the tetralyl naphthyl 6-acetamide were less toxic than the simpler related compounds, which may be linked to the increase in molecular weight. This increase is on the side chain in the case of the former compound and on the ring in the latter. On the other hand, the highly effective naphthyl butyric acid has a higher molecular weight than the less active naphthyl acetic acid. With leafy greenwood cuttings the more complex compounds were often so similar in action to the simpler substances that only by long continued experimentation with a wide variety of subjects could exact comparisons be made.

The conclusions drawn from this data add an additional complication to the use of growth substances. The inferior results with the amide growth substances reported by Swartley and Chadwick (5) are clearly understandable. These data demonstrate the existence of certain fundamental physiological differences between different groups of plants for which a satisfactory explanation cannot be offered at present. Growth substances have customarily been applied as the free acids or sometimes as their esters or potassium salts. These particular forms, however, cannot be regarded as the most effective substances for cuttings of all plants, and the supplementary use of other forms, such as the amides, must now be considered.

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Some Problems Affecting the Rooting of Hardwood Blueberry Cuttings[1]

By A. E. Stene and E. P. Christopher, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

IN 1938 the Rhode Island Agricultural Experiment Station conducted an experiment designed to study the effect of ventilation on hardwood blueberry cuttings during the pre-rooting period, and of sand and peat, and peat alone as a rooting medium. Incidentally, observations on the type of frame used entered into the discussion of results. The presence of damping-off diseases interfered seriously with the rooting of the cuttings and it was therefore decided in 1940 to repeat the experiment on a larger scale, giving special attention to disease control. The experiment was outlined as follows:

A. Type of frame.
   1. High box-frame (36 inches high) with rooting medium in wire mesh bottom trays suspended about 6 inches below the hotbed sash.
   2. A common cold-frame with trays similarly suspended having an air space under the trays approximately 6 inches in depth.
   3. A common cold-frame with the propagating medium laid on a base about 10 inches in depth consisting of boulders 4 to 6 inches in diameter covered with coarse and fine gravel.

B. Amount and Duration of Ventilation.
   1. Continuous ventilation given by raising sash 1 inch at one end from the time when the first leaves emerged.
   2. No ventilation until after the cuttings rooted.
   3. Continuous partial ventilation by covering the sash with sheeting but with no glass sash.[2]

C. Rooting Medium.
   1. All Holland peat.[3]
   2. Peat, three parts; sand, one part by measure.

D. Disinfection of rooting medium to prevent development of damping-off diseases. The work was done under direction of Frank L. Howard, station plant pathologist, and the following treatments were arranged so as to include 14 of the 56 compartments:
   1. Steam.
   2. Chloropicrin.
   3. Formaldehyde.
   4. Check.

Five cold-frames and two high box frames were used with each

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[1]Contribution No. 589 of the Rhode Island Agricultural Experiment Station.

[2]Growth under sheeting was so poor that data are not included.

[3]The peat available varied considerably from a very fine texture to coarsely granular.

frame subdivided into eight sections. The frames were shaded with a very coarse burlap, supplemented from 9 a. m. to 4 p. m. on sunny days with lath shades in which the laths were quite widely spaced. The frames were watered thoroughly once or twice a week depending on weather conditions.

Disinfection for Disease Control

All cuttings were dipped in a yellow cuprocide solution, 1 ounce to 3 gallons of water, before setting, in an effort to eliminate cutting borne organisms as a variable. Two sections in each frame were treated with chloropicrin injected into the soil in 2 cubic centimeter doses, 12 inches apart; two were treated with formaldehyde solution applied at the rate of 1 gallon of a 1–50 solution per cubic foot; two were steam sterilized for ½ hour, and two served as checks. The formaldehyde solution was also applied to wooden frames where the soil was treated outside the frames.

Three varieties of blueberry cuttings were used, namely; Pioneer, Rubel, and Cabot. In each section 30 cuttings of Pioneer and 10 each of Rubel and Cabot were planted. Considerable difficulty was experienced in purchasing cuttings, and planting was delayed so that many buds had swollen and some were unavoidably rubbed off in handling. Many cuttings were slow in starting and from one-quarter to one-third of cuttings made feeble growth or failed to start at all.

Discussion

The percentage of rooting in cold-frames was better than in box-frames (Table I) and appears to substantiate the conclusion that the cheaper cold-frame is as likely or even more likely to give satisfactory results. Likewise, drainage and aeration provided by a rock and gravel base gave about as good results as the more expensive trays with wire cloth bottoms. There may be an advantage in the use of the latter since the trays can be removed when the cuttings have rooted and the frames used for other purposes.

Peat alone as a growing medium appears to be satisfactory and the addition of sand unnecessary. The sections containing coarse granular peat produced distinctly the better results, possibly because the finer

TABLE I—The Rooting of Blueberry Cuttings with Various Media and Treatments

Treatment	Cold Frame		Box Frame	
	Number of Cuttings	Rooted (Per Cent)	Number of Cuttings	Rooted (Per Cent)
Rock Base	800	35	—	—
Wire bottom tray	800	37	800	25
Ventilated	800	37	400	25
Not ventilated	800	35	400	25
Peat	800	39	400	29
Peat and sand	800	33	400	20
Steam	400	28	200	18
Chloropicrin	400	39	200	22
Formalin	400	39	200	31
Check	400	42	200	24

peat held too much water and interfered with aeration of the underground part of the cuttings.

The question of ventilation appeared to be unimportant although the question of its influence on damping-off diseases is still to be considered as indicated in the 1938 experiment (1). The frames at that time, however, were located between wings of the greenhouse while this year the frames were in the open, exposed to prevailing winds. Evidence of disease was practically absent in untreated as well as in treated sections. It is possible that the sand and peat used were practically free from disease organisms and that if any were present on cuttings the dipping of cuttings before setting prevented infection.

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Inheritance of Some Characteristics in Strawberry Varieties

By E. B. MORROW, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*, and GEORGE M. DARROW, *U. S. Horticultural Station, Beltsville, Md.*

IN Eastern North Carolina, as well as in the whole South, the Blakemore, Klondike, and Missionary varieties constitute over 95 per cent of the acreage. The Blakemore, introduced in 1929, is now more widely grown than either of the other two. However, in the last few years growers in Eastern North Carolina have found the production of the more highly flavored Dorsett and Fairfax varieties profitable even though they are better adapted to regions farther north. This situation led to the introduction in 1938 of the Fairmore, Daybreak, and Eleanor Roosevelt varieties and in 1940, the Massey variety. Thus since 1928, when the breeding work for North Carolina began, several important varieties have been introduced.

The progress of the breeding work during this period has indicated the desirability of a much more extensive survey of the possibilities of very greatly improving strawberries. The large size of the Marshall raised on the Pacific Coast and of the Catskill recently introduced in New York State, and the rich flavors, freezing qualities, firmness and disease resistance of some seedlings obtained in the breeding work have suggested immensely greater improvements that might be made.

To estimate the possibilities, a systematic survey is needed of the desirable qualities in existence. This means a survey of the characteristics of the wild species and of the cultivated varieties of the world such as was reported in the Yearbook of the United States Department of Agriculture in 1937. It also means a more intensive survey for any one region, such as North Carolina, of the qualities needed and of the best means of obtaining such qualities. Because of the humidity and high temperatures at fruiting time in Eastern North Carolina a firmer berry is needed than in most regions. The causes of firmness and sources of breeding stock with firm fruit need to be determined. The cause of second cropping and its inheritance need to be understood. In North Carolina systematic surveys have been undertaken on the inheritance of certain characteristics in both selfed lines and crosses. This paper contains a partial summary of the information obtained during 1939 and 1940.

METHODS

Pollinations were made at Raleigh, North Carolina, and at Beltsville, Maryland. The seedlings were grown at Raleigh and planted in the field at Willard, North Carolina, near the center of the commercial strawberry area of the State. The plants were set in the field during the first half of July in both 1938 and 1939. Each seedling (mother plant) was permitted to produce two runner plants. The clone referred to in the text is, therefore, composed of a mother plant and two daughter plants except for those seedlings which failed to produce

runners. The runners were rooted on either side of the mother plant at right angles to the row axis. The 1938 seedlings were fruited in both 1939 and 1940. The data on the 1939 seedlings cover only the 1940 fruiting season.

Because of weather conditions the records are more complete for some characteristics than for others. For example, the mild winter of 1938–1939 was unusually favorable for observations on winter flowering. Also, leaf scorch and leaf spot were much less prevalent than usual when most of the records were taken. The number of selections per cross will, therefore, certainly change as soon as a season occurs which is more favorable for the spread of these diseases.

Winter Flowering and Second Cropping

Under Eastern North Carolina conditions most commercial strawberry varieties flower to some extent during mild winters. In some seasons the early crop of fruit may be materially reduced because of cold damage to these early-blooming clusters. During the milder winters the earliest clusters may be killed entirely, while in somewhat colder winters only the primary flowers on a cluster may be caught by late winter or early spring freezes. Even though many flowers may be killed, fruit bud formation continues throughout the winter and early spring months. Under these conditions the most widely grown varieties usually produce two peak crops: the early or "ground" crop and the late or "crown" crop.

The mild winter of 1938–1939 offered an opportunity to observe winter flowering on a number of selfed varieties and crosses. January was relatively mild, and unusually warm weather occurred during the first 10 days of February, followed by temperatures below freezing on February 12 and 13. In Table I, line (a), is given the flower history of seedlings which had bloomed prior to February 12. It is notable that many more selfed seedlings of Blakemore and Missionary, the two most important varieties in the Willard area, had flowered by the middle of February than of any other other selfed variety or even of any cross. Selfed seedlings of Fairfax and Fairmore were distinctly later. For Blakemore and Missionary 67 per cent of the seedlings had flowered by February 12 compared with 5 per cent for Fairfax and 11 per cent for Fairmore.

The remainder of February was relatively mild except for below-freezing temperatures on the 23rd and 24th. The first half of March was also quite warm, but freezing weather occurred on the 17th, 19th, and 20th, so that all strawberry flowers and young fruits were killed. The flower history of seedlings which failed to bloom before February 12, but which bloomed between February 12 and March 17, is given in Table I, line (b). Most of the seedlings for any selfed line or cross had flowered by March 17, line (a) plus line (b). Late-flowering plants are given in Table I, line (c).

The complete flower history for any selfed line or cross shows that the plants with the most flowers killed also generally produced the most flowers in both the early and crown crops. For example, the 67 selfed seedlings of Missionary which had 40 flowers per clone killed by

TABLE I—FLOWER PRODUCTION DURING 1939 IN 1938 SELFED LINES AND CROSSES

Total No. of Seedlings	No. of Seedlings Flowering	Flowers Killed by Cold		Flowers Escaping Cold Damage			
				Early Crop Flowers		Crown Crop Flowers	
		No. of Clones	Flowers Per Clone	No. of Clones	Flowers Per Clone	No. of Clones	Flowers Per Clone
			Fairfax selfed				
99	(a) 5	5	14.0	5	35.8	4	36.5
—	(b) 70	70	5.8	69	14.8	30	10.3
—	(c) 16	—	——	16	10.2	7	6.7
			Fairmore selfed				
100	(a) 11	11	26.1	10	19.8	10	44.5
—	(b) 60	60	9.7	57	11.8	30	16.7
—	(c) 7	—	——	7	11.7	0	0
			Southland selfed				
100	(a) 18	18	33.1	18	15.3	14	30.7
—	(b) 70	70	12.4	66	12.3	55	21.7
—	(c) 9	—	——	6	6.8	5	16.8
			E. Roosevelt selfed				
96	(a) 22	22	21.8	21	14.0	11	11.5
—	(b) 58	58	8.3	54	13.6	43	9.6
—	(c) 11	—	——	8	4.5	4	11.5
			Blakemore selfed				
99	(a) 67	67	21.6	66	25.0	60	30.4
—	(b) 29	28	9.3	27	14.1	24	23.5
—	(c) 3	—	——	3	4.0	2	26.0
			Missionary selfed				
99	(a) 67	67	40.0	67	54.0	65	33.3
—	(b) 30	30	13.0	30	39.0	28	30.4
—	(c) 2	—	——	2	14.0	0	0
			Daybreak selfed				
100	(a) 27	27	41.5	27	43.3	23	36.3
—	(b) 65	65	16.8	65	29.4	39	28.1
—	(c) 2	—	——	2	5.5	2	16.0
			N. C. 225 × Fairfax				
95	(a) 29	29	27.1	28	42.9	27	23.9
—	(b) 61	61	10.7	61	37.9	43	15.8
—	(c) 4	—	——	3	55.0	4	14.0
			Blakemore × Fairfax				
100	(a) 45	45	28.9	44	41.2	40	30.3
—	(b) 50	50	10.5	50	28.4	40	25.9
—	(c) 1	—	——	1	48.0	0	0
			Fairmore × Daybreak				
100	(a) 29	29	41.8	27	48.6	27	46.2
—	(b) 63	63	18.4	64	32.4	47	41.3
—	(c) 6	—	——	4	6.0	3	13.3
			N. C. 225 × Fairmore				
100	(a) 43	43	26.0	43	48.1	41	27.7
—	(b) 55	55	11.1	55	33.5	49	24.6
—	(c) 1	—	——	1	35.0	1	35.0

cold, came through with 54 flowers for the early crop and 33 flowers per clone for the crown crop. Early flowering seems to be an excellent index of productiveness under Eastern North Carolina conditions. Apparently conditions which make for early flowering also make for further extensive fruit bud formation. As indicated in Table I, most winter flowering seedlings also produced crown crops.

Early Ripening

In April, 1940, the surviving seedlings of the 1938 planting and all of the 1939 planting were observed for early ripening. The percentage of early ripening seedlings for each progeny is given in Table II. Missionary selfed had many more early seedlings than any other selfed variety of the 1938 planting. Of the 1939 planting, N. C. 640 selfed had more early seedlings than any other selfed selection or variety. This record seems to give a correct indication of the genetic earliness of the varieties. The differences between the crosses are even greater than the differences between the selfed lines. Over half of the N. C. 225 x Fairmore and and Blakemore x N. C. 640 crosses were in the early-ripening group.

Fruit Characteristics

Table III gives the characteristics of the berries. As a practical measure, the largest berry from each clone was used to represent the

TABLE II—Seedlings Ripening as Early as Blakemore in 1940 and Per Cent of Selection Saved for Further Testing

	Total No. of Seedlings	Per Cent of Seedlings With Early Fruit*	Selections Transplanted (Per Cent)
	1938 Seedlings		
Blakemore selfed	382	18.3	2.1
Daybreak selfed	116	12.9	2.6
E. Roosevelt selfed	88	1.1	1.1
Fairfax selfed	203	1.0	0.5
Fairmore selfed	85	1.2	1.2
Missionary selfed	120	33.3	1.7
Southland selfed	145	4.8	3.4
Blakemore × Fairfax	208	11.1	1.9
Fairmore × Daybreak	118	19.5	0
N.C. 225 × Fairfax	126	27.0	4.0
N.C. 225 × Fairmore	102	55.9	1.0
	1939 Seedlings		
Fairmore selfed	52	1.9	1.9
Klondike selfed	53	1.9	0
Klondike (F_2) selfed	267	3.7	0
Massey selfed	211	0.5	2.4
Missionary (F_2) selfed	59	—	0
N.C. 866 selfed	136	2.2	2.9
N.C. 640 selfed	95	26.3	3.2
Blakemore × Dresden	113	13.3	0.9
Blakemore × Massey	292	7.5	3.8
Blakemore × Missionary	158	33.5	0
Blakemore × N.C. 640	195	55.9	2.1
Catskill × Blakemore	305	10.2	1.3
Catskill × Fairmore	379	1.6	1.1
Catskill × Massey	338	3.8	0.9
Catskill × N.C. 866	295	3.7	0
Daybreak × N.C. 855	52	7.7	0
Dorsett × N.C. 866	340	7.3	0.9
Dresden × Blakemore	22	—	0
Fairmore × Dresden	87	8.0	2.3
Fairmore × N.C. 866	92	2.2	1.1
Fairmore × N.C. 640	669	27.1	4.9
Massey × Fairmore	335	1.8	3.6
Massey × N.C. 640	258	16.3	3.1
Maytime × Daybreak	30	23.3	6.7
Missionary × Blakemore	47	23.4	0
N.C. 855 × Daybreak	156	25.6	1.9
N.C. 640 × Massey	183	17.5	3.8
N.C. 640 × Redheart	285	15.1	3.5
N.C. 302 × Dorsett	121	—	7.4
Rockhill × N.C. 855	132	38.6	0

*Per cent with fruit ripe April 25, 1940.

TABLE III—CHARACTERISTICS OF THE LARGEST BERRY FROM 100 SEEDLINGS OF EACH PROGENY (DATA BASED ON 100 PLANTS EXCEPT AS NOTED, CHARACTERISTICS GIVEN IN PERCENTAGES)

Fruit Characteristics	Blakemore Selfed	Missionary Selfed	Fairmore Selfed	N. C. 640 Selfed	N. C. 866 Selfed	Fairfax Selfed	Daybreak Selfed	E. Roosevelt Selfed	Southland Selfed	Blakemore × Missionary	Blakemore × Dresden	Blakemore × Massey	Blakemore × Fairfax	Catskill × Blakemore	Blakemore × N. C. 640	Catskill × Massey	N. C. 225 × Fairmore	Catskill × Fairmore	Fairmore × N. C. 640	Catskill × N. C. 866
Number of Berries																				
	100	100	58	57	62	95	100	36	100	100	100	100	100	100	100	100	100	100	100	100
Average Berry Weight (Gms)																				
	9.4	9.2	8.6	8.9	10.7	11.5	8.2	11.7	11.2	14.0	18.5	17.9	13.0	16.2	14.5	17.7	12.7	14.9	16.0	18.2
Berry Shape																				
Very irregular	—*	0	0	75	—*	0	0	8	0	0	0	28	3	42	20	50	0	0*	1	12
Necked	—*	3	17	0	3	0	47	—*	1	8	6	2	—*	5	3	2	6	22	5	18
Doubled	10	4	0	2	5	0	0	6	2	15	3	10	8	10	3	4	10	—*	23	1
Tendency to doubling	11	0	3	9	—*	0	2	—*	2	14	6	5	2	3	13	6	7	—*	9	0
Wedge-shaped	5	7	9	58	3	28	18	17	12	28	17	0	28	43	24	48	11	—*	—*	37
Conic	54	88	84	2	76	72	74	39	38	42	80	79	37	36	45	34	71	14	—*	48
Globose	—*	0	0	25	—*	0	5	—*	46	0	0	5	5	3	15	6	0	0	3	0
Berry Color																				
Too dark	0	5	17	16	0	13	15	3	6	0	0	1	2	0	0	1	0	6	5	0
Too light	6	1	2	2	3	0	0	0	6	7	6	17	1	20	17	15	10	0	0	13
Deep red	0	24	81**	68	0	48	85	97**	22	33	10	16	11	0	16	6	31	94**	95**	0
Medium red	94	70	0	14	97	39	0	0	66	60	84	66	86	80	67	78	59	0	0	87
Seeds																				
Raised	12	4	52	32	6	14	12	8	2	19	9	15	7	6	20	17	29	—*	34	10
Sunken	4	1	0	0	0	4	1	3	35	24	19	15	3	86	29	17	2	—*	0	26
Even	84	95	48	68	94	82	87	89	63	57	72	70	90	8	51	66	69	—*	66	64
Seed Color																				
Yellow	50	12	45	39	19	31	24	11	5	33	80	35	46	5	21	23	75	10	30	26
Green	0	2	15	0	3	0	12	6	5	4	6	8	0	0	3	0	0	15	5	1
Very dark	0	8	0	0	0	0	0	0	0	0	4	3	0	0	6	0	0	0	0	0
Average	50	78	40	61	78	69	74	83	90	63	10	54	54	95	70	77	25	75	65	73

Fruits																				
Soft	12	50	5	35	8	15	50	14	80	84	94	78	—*	96	73	87	60	59	25	94
Firm	88	50	95	65	92	85	50	86	20	16	6	22	—*	4	27	13	40	41	75	6
Caps																				
Too tight	30	40	9	32	11	58	5	28	50	30	34	29	33	20	26	36	38	12	20	9
Not tight	70	60	91	68	89	42	95	72	50	70	66	71	67	80	74	64	62	88	80	91
Caps																				
Too large	0	0	0	0	5	1	0	9	0	0	0	0	1	0	0	2	0	0	0	8
Too small	2	4	7	9	2	7	2	0	1	1	4	0	0	2	6	3	7	11	4	2
Average size	98	96	93	91	93	92	98	91	99	99	96	100	99	98	94	95	93	89	96	90
Flesh																				
Solid	20	48	60	86	77	68	63	83	55	—*	29	33	55	40	33	33	50	50	39	25
Large cavity	52	32	14	9	10	13	11	3	20	—*	38	40	17	30	32	40	29	18	43	28
Small cavity	28	20	26	5	13	19	26	14	25	—*	33	27	28	30	35	27	21	32	18	47
Flesh Color																				
Too light	16	7	24	0	10	47	26	19	50	—*	20	33	5	50	10	60	15	20	3	60
Light red	0	72	66	0	82	8	61	64	50	—*	1	67	62	49	76	38	72	80	23	40
Red	84	17	10	100	8	45	13	17	0	—*	79	0	23	1	14	2	13	0	74	0

*Records incomplete.
**Records taken before color was separated into medium and deep red classifications.

seedlings of a cross or of a selfed line. This seemed to give a fairly accurate picture of the berry characteristics of a progeny. The records for berry size, shape, color, and firmness, seed depth and color, calyx characteristics, and solidity and color of flesh indicate the inheritance of each characteristic. Thus the largest berries were borne by Blakemore x Dresden, Catskill x N. C. 866, Blakemore x Massey, Catskill x Massey, and Catskill x Blakemore. Selfed seedlings of Eleanor Roosevelt, Fairfax, and Southland averaged larger than those of Blakemore, Missionary, and Fairmore. N. C. 640 was notably irregular. Catskill x Massey and Catskill x Blakemore also had a high percentage of irregular berries. In the selfed lines the highest per cent of firm berries occurred in Fairmore, N. C. 866, Blakemore, Eleanor Roosevelt, and Fairfax. Southland selfed was notably soft. In the crosses, both Catskill and Dresden seemed to transmit a high degree of softness.

In the last column of Table II are given the percentages of the 1938 and 1939 progenies selected for further trial or for use in breeding. Many of the selections made at harvest time were discarded because of susceptibility to leaf diseases before transplanting to test plots in August. As shown, not one of the F_8 seedlings of Missionary or Klondike selfed seemed worth further trial. The most promising 1938 progenies containing as many as 100 seedlings were Southland selfed and N. C. 225 x Fairfax, while the most promising 1939 progenies were N. C. 302 x Dorsett, Fairmore x N. C. 640, Blakemore x Massey, N. C. 640 x Massey, Massey x Fairmore, N. C. 640 x Redheart, and Massey x N. C. 640. In all of these crosses the number of selections transplanted for field tests was above 3 per cent.

Transpiration in Strawberries as Affected by Root Temperature

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THIS paper is a second progress report on studies to determine the effect of environment (soil and air) upon transpiration and plant growth of different strawberry varieties.

During the trials reported in a previous paper (1) it was observed that at high temperatures strawberry plants wilted severely and in some instances did not fully recover. Two water baths were built to accommodate 10 water culture potometers in each bath and equipped with water circulating pumps and thermo-regulators. Low temperature was maintained in one bath by admitting cool water by an automatic thermo-regulated valve. High temperature was maintained in the other bath by two knife-type immersion electric heaters.

Preliminary trials indicated that at temperatures from 75 to 90 degrees F strawberry plants seemed to function normally, above 95 degrees F behavior was not normal and at 105 degrees the plants were seriously injured.

Tests With Water-Culture Potometers, 1939

From the results of the preliminary trials, 85 degrees F was selected for the cool temperature bath and 100 degrees F for the high temperature bath. Varieties selected for trial were: Aroma, Blakemore, Bellmar, Big Late, Catskill, Chesapeak, Clermont, Dorsett and Fairfax. Trials with each variety were replicated two or three times. Plants for trial were secured by plunging 4½ inch pots along the row and establishing vigorous runner plants, just beginning to root, in each pot. When the plants had developed five to seven fully expanded leaves they were taken up and the soil carefully washed from the roots. Old, injured, and partially expanded leaves were removed leaving four or five normal leaves on each plant. Plants were placed in the potometers (500 cubic centimeters aspirator bottles) by wrapping cotton around the crown and suspending the plant in the neck of the potometer. The plants were not sealed in, as reported in the previous paper since from repeated trials of several days duration water loss through cotton stoppers was found to be negligible.

Each trial was started at 9:00 a m and continued for a period of 48 hours. Three varieties of three plants each were used in each trial with Blakemore as the standard for comparison in each trial.

Water loss through transpiration was measured every 2 hours during the day (7:00 a m to 7:00 p m), by adding sufficient water through a graduated burette to bring the volume of water up to the original level in the potometers.

The plants showed marked differences in behavior at different root temperatures. At 85 degrees F the plants apparently functioned normally, no serious wilting was evident at any time and root development continued. At 100 degrees F wilting occurred during the heat of the

day on one or more leaves of practically all plants. In some instances this wilting was so severe that the leaves did not become normal during the night. The roots failed to continue normal growth even though the water was drained from the potometer after the first 24 hours and fresh water added. The smaller roots darkened in color and the parenchymatous tissue surrounding the vascular bundles in the petioles of practically all leaves turned brown.

The results of transpiration measurements show that plants may or may not transpire more at root temperature of 100 degrees F than at 85 degrees F during the first 24 hour period but in all instances transpiration during the second 24 hour period was much less at 100 degrees F than at 85 degrees F. Also at 100 degrees F transpiration rate declined during the second 24 hour period while at 85 degrees F transpiration rate was normal as indicated by comparison with the evaporating power of the air measured by Livingston's bulb atmometers. Some typical examples of transpiration rate is shown in Table I since space here does not permit complete tabulation of all results.

TABLE I—TRANSPIRATION OF SEVERAL VARIETIES OF STRAWBERRY PLANTS IN WATER AT ROOT TEMPERATURES OF 85 DEGREES AND 100 DEGREES F

Variety	Date (1939)		No. Plants	Total Leaf Area (Sq In)	Root Temperature (Degrees)	Transpiration (Cc Per Sq In)		
	Begun	Ended				1st 24 Hrs	2nd 24 Hrs	Total
Blakemore	Sep 4	Sep 6	3	61.59	85	1.95	2.82	4.77
Blakemore	—	—	3	65.82	100	2.00	1.54	3.54
Dorsett	—	—	4	69.54	85	1.60	2.33	3.93
Dorsett	—	—	4	74.10	100	1.65	1.32	2.97
Big Late	—	—	3	69.07	85	1.96	2.91	4.87
Big Late	—	—	3	57.62	100	1.88	1.50	3.38
Evaporation*	—	—	—	—	—	2.52	3.95	6.47
Blakemore	Sep 11	Sep 13	3	69.94	85	1.79	1.92	3.71
Blakemore	—	—	3	68.07	100	1.97	1.26	3.23
Dorsett	—	—	3	53.03	85	1.62	1.69	3.31
Dorsett	—	—	3	54.97	100	1.56	1.27	2.83
Fairfax	—	—	3	42.60	85	1.48	1.60	3.08
Fairfax	—	—	3	51.75	100	1.62	1.10	2.72
Evaporation*	—	—	—	—	—	2.84	2.88	5.72
Bellmar	Aug 14	Aug 16	3	65.34	85	1.69	1.83	3.52
Bellmar	—	—	3	63.63	100	1.83	1.00	2.83
Clermont	—	—	3	90.35	85	1.58	1.76	3.34
Clermont	—	—	3	72.04	100	1.46	0.23	1.69
Evaporation*	—	—	—	—	—	1.92	2.00	3.92

*Evaporation was measured with Livingston's bulb atmometers and calculated as cc per square inch of surface area.

TESTS WITH SOIL-CULTURE POTOMETERS, 1940

Since all varieties tested in water-culture potometers in 1939 were injured at 100 degrees F it was assumed that part of this injury might be due to insufficient aeration of the roots. Therefore to determine the effect of high root temperatures on transpiration under normal growing conditions 5-inch glazed pots were used in the temperature controlled water baths. Well developed runner plants having five to seven fully expanded leaves were potted in good potting soil in a porous pot and allowed to become established for a period of 10 days. The plants were then transferred to a glazed pot of the same size. A 1-inch tube was inserted to make possible the replacement of water lost through transpiration and the pots sealed with high melting point paraffin.

TABLE II—TRANSPIRATION OF FOUR VARIETIES OF STRAWBERRY PLANTS IN SOIL FOR FOUR DAYS AT ROOT TEMPERATURES OF 85 DEGREES AND 100 DEGREES F

Variety	Date (1940)		Number Plants	Root Temperature (Degrees)	Transpiration (Cc Per Sq In) for Each 24 Hr Period, 7:00 A M to 7:00 A M				
	Begun	Ended			1st	2nd	3rd	4th	Total
Blakemore	Jul 30	Aug 3	3	85	0.65	0.77	0.72	0.86	3.00
Blakemore	—	—	3	100	1.04	1.06	0.96	1.27	4.33
Dorsett	—	—	3	85	1.09	1.30	1.10	1.49	4.98
Dorsett	—	—	3	100	1.90	1.93	1.67	1.69	7.19
Chesapeak	—	—	4	85	0.73	0.88	0.81	0.94	3.36
Chesapeak	—	—	4	100	1.00	1.08	0.96	1.12	4.16
Evaporation	—	—	—	—	2.49	2.73	1.53	2.51	9.26
Blakemore	Aug 6	Aug 10	3	85	1.00	1.06	0.68	0.69	3.43
Blakemore	—	—	3	100	1.31	1.40	0.88	0.84	4.43
Dorsett	—	—	3	85	0.77	1.65	0.59	0.46	3.47
Dorsett	—	—	3	100	0.65	0.83	0.55	0.42	2.45
Clermont	—	—	4	85	0.96	1.10	0.81	0.65	3.52
Clermont	—	—	4	100	0.87	0.73	0.79	0.60	2.99
Evaporation	—	—	—	—	2.05	2.10	1.15	1.11	6.41

TABLE III—TRANSPIRATION OF BLAKEMORE AND DORSETT STRAWBERRY PLANTS IN SOIL AT ROOT TEMPERATURES OF 85 DEGREES F AND 100 DEGREES F

Days	Blakemore		Dorsett		Evaporation	Mean Day Temperature
	Root Temperature		Root Temperature			
	85 Degrees	100 Degrees	85 Degrees	100 Degrees		
Test 1—August 10 to 20, 1940						
1	0.74	0.78	1.15	1.30	1.35	89.5
2	0.77	0.85	1.00	1.45	1.53	90.5
3	0.83	0.85	1.41	1.53	1.60	96.5
4	1.08	0.89	1.40	1.72	1.89	100.0
5	0.84	0.82	1.00	1.43	1.53	94.5
6	0.44	0.59	0.39	0.74	0.69	85.0
7	0.34	0.40	0.41	0.47	0.36	83.5
8	0.73	0.59	0.83	0.98	0.90	91.0
9	0.98	0.70	1.12	1.22	1.44	89.5
10	1.00	0.73	1.18	1.41	1.89	86.5
Total	7.44	7.29	10.18	10.86	12.93	—
Per cent transpiration during day 7:00 a m–7:00 p m						
	88	72	92	82		
Per cent transpiration during night 7:00 a m–7:00 p m						
	12	18	8	17		
Test 2—August 20 to 30, 1940						
1	0.70	0.92	0.66	1.09	1.08	83.5
2	0.81	1.25	1.48	1.48	1.62	87.0
3	0.93	1.25	1.05	1.43	1.89	88.5
4	0.92	1.11	0.98	1.15	1.44	89.0
5	1.13	1.24	1.40	1.53	2.16	93.5
6	1.12	1.07	1.23	1.22	1.71	91.5
7	1.06	1.08	1.18	1.04	2.39	93.5
8	0.76	0.74	0.74	0.81	1.71	92.0
9	0.92	0.83	1.01	0.95	1.27	91.0
10	0.67	0.71	0.68	0.84	1.17	86.5
Total	9.34	10.26	10.50	11.60	11.60	16.39
Per cent transpiration during day 7:00 a m–7:00 p m						
	86	84	90	83		
Per cent transpiration during night 7:00 p m–7:00 a m						
	14	16	9	16		

The plants were weighed on a sensitive balance and readings taken every 4 hours during the day (7:00 a m to 7:00 p m) by adding water to bring plants back to original weights. Trials of 3- and 4-day periods were made from June 6 to August 10, 1940, using Blakemore, Chesapeak, Clermont and Dorsett varieties and two periods of 10 days each from August 10 to August 30 using Blakemore and Dorsett.

The results of the 3-day trials show that all varieties tested function normally throughout the entire period at 100 degrees F although the transpiration rate is higher than at 85 degrees F, also that transpiration rate has the same trend as evaporating power of the air.

The results of two 4-day trials shown in Table II indicate the same trend as the 3-day trials. The discrepancy during the second period may be due to cooler partly cloudy weather and showers during the third and fourth days.

The results of two 10-day trials shown in Table III and Fig. 1 also indicate that strawberry plants transpire at a higher rate at higher

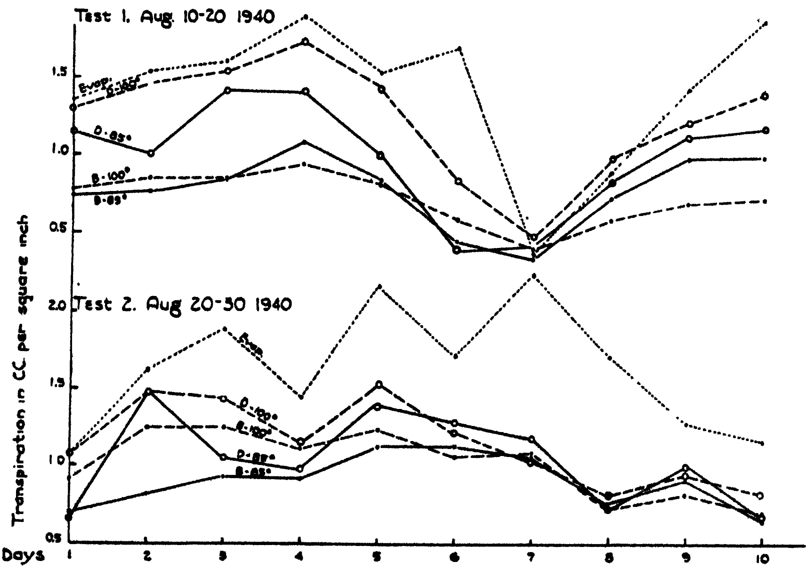

FIG. 1. Graph showing transpiration rate in cubic centimeters per square inch of Blakemore and Dorsett strawberries during two 10-day test periods compared with evaporating power of the air.

soil temperatures but that atmospheric humidity has a more direct influence on transpiration rate than air temperature.

Effect of High Temperature on Root Development

Observations of root development showed that the majority of the small fibrous roots had turned brown after 3 days exposure to a temperature of 100 degrees F. Although some root growth had occurred the new root growth was practically devoid of root hairs. In contrast, the root development at 85 degrees F was normal with no sign of

injury to fibrous roots. The same condition was apparent after the 4-day trial. Two representative balls of soil in Fig. 2 show the distribution of roots.

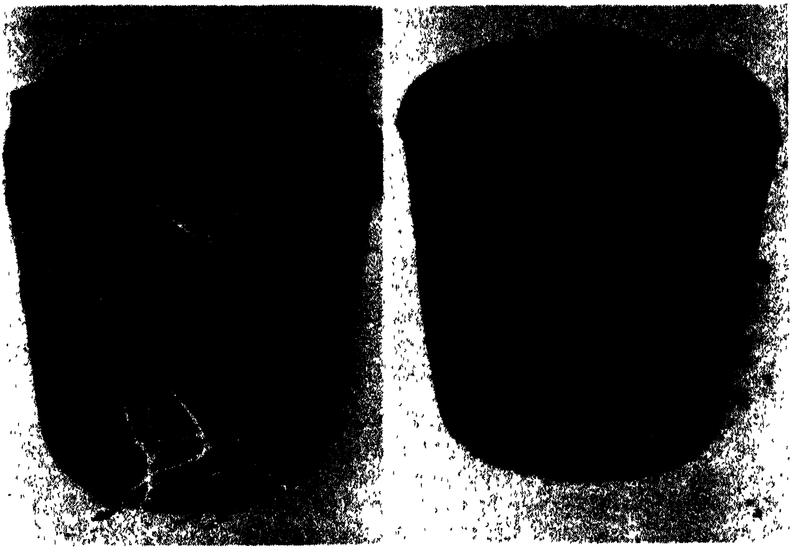

FIG. 2. Root distribution in soil culture potometers. Left, Dorsett roots showing normal appearance and development after 4 days at 85 degrees F; Right, Dorsett roots almost indiscernible due to browning after 4 days at 100 degrees F.

It is obvious that plants under field conditions will not be subjected to such continuous high temperatures but soil temperatures in the field are often higher than 100 degrees F. Furthermore when soil temperatures in the field are so high, moisture conditions are not as optimum for plant growth as those maintained throughout these trials.

From the results reported above it might be concluded that (a) soil culture potometers for measuring transpiration show more normal plant behavior than water-culture potometers; furthermore records taken by the two methods with the same type of plants may not always coincide. (b) The general trend seems to indicate that varieties of strawberries susceptible to injury from drought and high temperature have a higher transpiration rate than resistant varieties. (c) At high temperatures, root development is retarded and small roots are injured indicating that leaf scorch at high temperatures may be due to inability of roots to absorb moisture rapidly enough to prevent injury. (d) Evaporating power of the air has a more direct effect on transpiration rate than root temperature.

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Breeding Autumn-Fruiting Raspberries Under Oregon Conditions

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THE climatic conditions under which red raspberries are grown in the North Pacific Coast region of the United States are in many respects similar to that of Northwestern Europe. The raspberry varieties grown in this area have, however, originated almost entirely in the eastern part of the United States. When improvement of raspberries by breeding was begun, some European varieties were used as parents. The Lloyd George, the chief variety grown in England, was among those used because it seemed particularly well adapted to Pacific Coast conditions and because it was also autumn-fruiting. In Maryland it has also been used because of the very large size of its fruit but it has not been vigorous enough there to determine its autumn-fruiting characteristics.

Slate (1) has reported that seedlings of the Lloyd George and their offspring were the best source yet discovered for New York of the autumn-fruiting character in raspberries. At the Oregon Experiment Station the Lloyd George has been crossed with Cuthbert, Newburgh, Viking, Chief, Latham, Ranere and other varieties. Small numbers of open pollinated and selfed seedlings have also fruited. At Beltsville, Maryland, Lloyd George was crossed with Ranere.

Under normal autumn conditions in western Oregon and Washington the Ranere fruits early in the autumn, followed a little later by Lloyd George. These two varieties, therefore, have a relatively long period of fruiting. The Cuthbert variety also is autumn-fruiting under normal conditions but it does not bloom until late in the summer or early in the fall. Because of this later blooming and fruiting habit, the Cuthbert cannot normally be relied upon to give a profitable fall crop. At Beltsville, Maryland, the Ranere may start maturing its summer crop as early as the first part of August. Lloyd George is so weakened by disease and lack of hardiness in Maryland that its fall fruiting habit there is not known. When the most fruit of a selection or seedling ripens in August it is considered early autumn-fruiting. But when the fruit ripening season is in September it is considered as mid-season and if the fruit ripens mainly in October or later, such seedlings are considered as late-ripening.

The largest number of seedlings came into full fruiting during the summers of 1936 and 1937. The notes on the fall-fruiting habit of seedlings at Corvallis, Oregon, are given in Table I. This table also classifies seedlings according to the time when most of the fall fruit ripens.

Table I shows that the cross Lloyd George x Ranere gives a high percentage of early autumn-fruiting seedlings. The cross Cuthbert x Lloyd George gave few early fall-fruiting seedlings but a large percentage ripening in mid-autumn. Seedlings of the Viking x Lloyd

TABLE I—INHERITANCE OF FALL BEARING IN SEEDLINGS OF RED RASPBERRY CROSSES (CORVALLIS, OREGON)

Cross	Total Number of Seedlings	Total Per Cent Fall Bearing	Per Cent Fall Bearing		
			Early	Mid-Fall	Late Fall
		Fall, 1936			
Ranere × Lloyd George.......	39	90	67	10	13
Lloyd George × Ranere.......	63	78	40	25	13
Cuthbert × Lloyd George	118	68	20	27	21
Lloyd George × Cuthbert	197	40	5	19	16
Viking × Lloyd George	139	21	3	14	4
Newburgh × Lloyd George.. .	147	13	2	5	6
Latham × Lloyd George......	8	12	12	0	0
Chief × Lloyd George	147	4	0	2	2
Lloyd George × Chief.........	245	2	1	1	0
Lloyd George × Newburgh....	18	0	0	0	0
Newburgh × Chief...........	53	0	0	0	0
			Per Cent With Much Fruit	Per Cent With Little Fruit	
		Fall, 1937			
Lloyd George × Cuthbert.....	202	14	3	11	
U S 231 × Cuthbert....	180	5	2	3	

George cross were similar in this respect to Cuthbert x Lloyd George. A small number of seedlings of the Newburgh x Lloyd George cross fruited in mid and late autumn. Both U S 231, which is a purple selection, and Chief when crossed with Lloyd George produced very few fall-fruiting seedlings.

Selections made in 1936 and fruiting in 1940 having possible commercial value as fall-fruiting plants were largely seedlings of crosses between Cuthbert and Lloyd George. Still further evidence of the value of the different varieties as parents of autumn-bearing raspberries was gained when all the selections in Oregon now fruiting for a commercial test was classified for this characteristic in Table II.

TABLE II—PER CENT OF EARLY AND LATE FALL BEARING AMONG RED RASPBERRY SELECTIONS (1940 SEASON — CORVALLIS, OREGON)

Parentage	Number of Selections	Percentage	
		Early Fall Bearing	Late Fall Bearing
Newburgh × Chief.....	4	0	0
Newburgh × Lloyd George	32	13	22
Chief × Lloyd George	20	5	0
Lloyd George × Chief	15	0	0
Ranere × Lloyd George.............	6	50	0
Viking × Lloyd George.............	20	10	10
Cuthbert × Lloyd George...........	34	50	29
Lloyd George × Cuthbert...........	38.	13	45
Newburgh open....................	4	25	50

As shown in this table the largest percentage of selections which are early autumn bearing have Cuthbert and Lloyd George as parents.

The parents of the best fall-fruiting selections at Corvallis, Oregon, for the last 3 or 4 years have been Cuthbert and Lloyd George. These best selections are productive with deep red, high flavored fruit. The berries are firm and the spring crop is particularly valuable for canning, freezing and even long distance shipping. There is, however, a

tendency among some of these selections to grow late into the fall, as does Cuthbert. Such growth is susceptible to winter killing.

Only one Oregon selection of the cross between Ranere and Lloyd George is still under serious consideration as a commercial variety. Selections of this cross although early fruiting have been small and relatively poor in quality, and the plants lack vigor and fruitfulness. At Beltsville, Maryland with much larger numbers in the Lloyd George x Ranere cross promising selections of this parentage have been made. As shown in Table IV, 8.7 per cent were earlier than Ranere in the spring, 58 per cent fruited a second time, and 68 per cent were self fertile.

Many seedlings of crosses between autumn-fruiting selections fruited quite heavily during the autumn of 1940. These seedlings were irrigated in July, and autumn rains were unusually early and heavy. Due to the rain it was not possible to determine the quality of the fruit. The data given in Table III show that the selfed seedlings of Lloyd

TABLE III—PER CENT OF EARLY, MID- AND LATE-FALL-BEARING RED RASPBERRY SEEDLINGS (1940 SEASON — CORVALLIS, OREGON)

Parentage	Total Number of Seedlings	Per Cent in Bloom Aug 13	Per Cent in Fruit Sep 11 to 30	Per Cent With Good Set of Fruit Sep 11 to 30
Lloyd George selfed	38	55	76	76
Cuthbert selfed	19	42	42	32
140—(Cuthbert × Lloyd George) selfed	118	37	49	33
141—(Cuthbert × Lloyd George) selfed	64	40	48	28
189—(Cuthbert × Lloyd George) selfed	26	0	58	0
273—(Ranere × Lloyd George) selfed	45	31	47	20
340—(Newburgh × Lloyd George) selfed	36	0	14	3
363—(Chief × Lloyd George) selfed	26	0	4	0
420—(Newburgh × Lloyd George) selfed	96	0	11	9
542—(Newburgh × Chief) selfed	28	14	18	14
93—(Lloyd George × Plum Farmer) × 309 (Ranere × Lloyd George)	209	60	75	60
142—(Cuthbert × Lloyd George) × 273 (Ranere × Lloyd George)	158	51	71	47
142—(Cuthbert × Lloyd George) × 379 (Newburgh × Lloyd George)	121	48	91	85
273—(Ranere × Lloyd George) × 142 (Cuthbert × Lloyd George)	59	42	56	32
420 × Cuthbert	142	2	12	12
Taylor × Red Cross	77	1	4	2
Newburgh × Pynes' Royal	60	0	0	0
Latham × Preussen	20	0	0	0

George gave a very high percentage of productive seedlings. Seedlings of Cuthbert selfed showed about the same percentage of fall fruitfulness as did the best selections of Cuthbert x Lloyd George.

The selfed selections of Newburgh x Lloyd George and Chief x Lloyd George showed little tendency to fall bearing. The selection of Newburgh x Chief when selfed, however, produced some fall-fruiting seedlings. The crosses between the fall-bearing selections 93, 142, 273, 309 and 379 all showed high percentages of autumn-bearing seedlings in the progeny. Seedlings resulting from the cross of selection 420 (Newburgh x Lloyd George) with Cuthbert show relatively little tendency to fall fruitfulness. The crosses in which Taylor, Newburgh, Latham, Red Cross, Pynes' Royal and Preussen were used showed the least tendency toward autumn fruiting.

TABLE IV—INHERITANCE OF FALL-FRUITING, STERILITY AND EARLINESS IN SEEDLINGS OF LLOYD GEORGE x RANERE AT BELTSVILLE, MARYLAND (1937 AND 1938)

Characteristic	Number Seed-lings	Per Cent	Characteristic	Number Seed-lings	Per Cent
Fruiting Season			Self-sterile only	66	25
Fall fruiting	333	32	Self- and cross-sterile	17	7
Summer and fall fruiting	272	26	*Earliness*		
Not summer or fall fruiting	451	42	Earlier than Ranere	62	8.7
Sterility			With or later than Ranere	710	91.3
Self fertile	177	68			

The data on selfed seedlings of fall-fruiting selection (No. 273) of the Ranere x Lloyd George cross showed only 47 per cent with fruit in September. This is about the same as for the three selections of Cuthbert x Lloyd George parentage but not so great as for the secondary crosses involving Ranere or Lloyd George. Lloyd George selfed also gave a high percentage of fall-fruiting seedlings.

DISCUSSION AND CONCLUSIONS

Slate pointed out some effects of environment on the expression of autumn-fruiting and noted that vigorous plants fruit earlier and better than do weak plants. Furthermore, spring, summer, and fall fruiting in the raspberry should be thought of as responses to day length and temperature conditions. The tendency to form fruit buds seems to begin earlier and to develop more rapidly in fall fruiting raspberries. Fruit-bud formation begins in the terminal buds of the canes as soon as they cease to elongate rapidly. These terminal buds rapidly develop fruiting laterals which flower and fruit. Buds lower down do not begin so soon and do not develop into flower until the following spring. In all red raspberries fruit-bud formation is most rapid in the terminal buds and least rapid in the basal buds. Ranere which forms fruit buds earliest and in the longest days of summer is followed by Lloyd George, while Cuthbert does not form fruit buds until early autumn. Such spring-bearing varieties as Latham, Chief, Viking, and Newburgh do not begin fruit-bud formation until so late that usually no flowers appear until spring.

In Oregon most of the F_1 progeny of crosses between Lloyd George and Ranere matured early in the fall but the seedlings were lacking in the most desirable qualities and therefore selections with this parentage have gradually been discarded. The percentage of early fall-fruiting seedlings of the Cuthbert and Lloyd George cross was relatively small, most of the seedlings ripening in mid and late fall. However, the early fall-fruiting seedlings show many desirable characters and the most promising selections for commercial production are of this cross. Crosses of both Newburgh and Viking with Lloyd George gave some early fall fruiting seedlings but so few that these varieties cannot be considered as among the best parents for fall fruitfulness.

The cross, Lloyd George x Chief, gave very few fall-fruiting seedlings. Likewise crosses of Lloyd George with other varieties, such as Latham, Potomac, U S 231, and Plum Farmer, occasionally gave

fall-fruiting seedlings, but too few and too poor to be promising.

The results of selfing indicate that this may be a means of determining the value of a variety as a parent when fall fruitfulness is desired. The results of crosses between Cuthbert and Lloyd George and the high percentage of fall fruiting seedlings in their selfed progeny indicate that these varieties are the best to use in so far as breeding for autumn fruitfulness in the north Pacific Coast region is concerned.

The breeding work in Oregon agrees with that of Slate (1) in New York in that Lloyd George is the best parent for fall fruiting. The ability of Lloyd George to transmit fall fruiting to much of its progeny, however, seems to depend upon the tendency to fall fruitfulness in the variety with which it is crossed.

In Maryland the cross Lloyd George x Ranere has proved promising for the production of summer- and fall-fruiting varieties, Lloyd George having contributed size of fruit, and Ranere both adaptation to climate and summer fruiting.

Because of difficulty in classifying the seedlings it is not easy to picture the inheritance of the fall-fruiting character. In Oregon 80 per cent of the seedlings and in Maryland only 58 per cent of the Lloyd George x Ranere cross fruited a second time. Of the Maryland seedlings 32 per cent were fall fruiting only, while 26 per cent were both summer and fall fruiting only. It is probable that there are at least two allelomorphs: (a) spring fruiting only, and (b) spring and fall fruiting.

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The Relationship of Different Methods of Expressing Size of Blueberry Fruits

By F. B. CHANDLER, *Maine Agricultural Experiment Station, Orono, Me.*

THERE have been several measurements of blueberry size used in the past few years. This paper aims to present the relation of the different size measurements particularly as they apply to low-bush blueberries in Maine. It is also hoped that this article will enable research workers to estimate the number of berries per cup from the measurement of only the largest berries.

The author is fully aware of the danger of extrapolation but measuring the entire population or machine sampling is time consuming and may injure the fruit, therefore estimations may have a place. Furthermore the errors from extrapolation may not be large.

The diameter of each berry expressed in millimeters has usually been used as a measure of small samples of blueberries while for large samples the diameter of the largest berries sometimes is used. On the other hand the number of berries per cup has been used as a measure of the size of blueberries for large samples and particularly for commercial grades. In a few cases the mean diameter has been used to express size.

In 1939 and 1940 the distribution of 11,710 blueberry sizes was studied and as would be expected they formed a normal curve. When the data for samples with the same mode are combined and the curves for each group are plotted the curves are found to be very similar. Therefore it would be expected that there would be an association between the mean diameter of all of the berries and the diameter of the largest berry. The correlation coefficient of the mean diameter of all of the berries and the diameter of the largest berry is +0.712±.040. The correlation coefficient of the mean diameter of all of the berries and the mean diameter of a 3 per cent sample including the largest berries is +0.793 ±.030. The latter measure gives a correlation sufficiently large so that it may be used to estimate the mean diameter of all the berries.

When the data for the

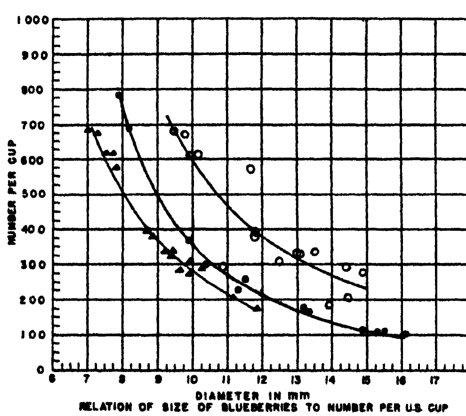

FIG. 1. The relation of number of berries per cup and the diameter. Solid dot, mean diameter of all berries 1939. Solid triangle, mean diameter of all berries 1940. O, mean diameter of 3 per cent sample including the berries (1940).

TABLE I—RELATION OF DIFFERENT BLUEBERRY SIZE MEASUREMENTS*

Mean Diameter of 3 Per Cent Sample Including the Large Berries	Number of Berries Per Cup	Diameter of Largest Berry	Mean Diameter of All Berries
10.0	600	10.9	7.55
10.5	540	11.2	7.73
11.0	480	11.6	8.05
11.5	425	12.0	8.45
12.0	375	12.6	8.91
12.5	340	13.1	9.34
13.0	310	13.7	9.75
13.5	285	14.2	10.17
14.0	265	14.7	10.41
14.5	247	15.2	10.72
15.0	230	15.8	11.00
15.5	217	16.3	11.22

*The standard error of curvilinear trend for the number of berries per cup and the mean diameter of a 3 per cent sample including the large berries is ±77 and for the number of berries per cup and the diameter of the largest berry is ±86.

number of berries per cup and the mean diameter of the berries are plotted it is found that the relationship is curvilinear (Fig. 1 and Table I). The curve for the 1939 data and the 1940 data do not coincide but have approximately the same trend. When the data are analyzed the correlation index for curvilinear relationship is 0.9997±.0001 for the 1939 data and 0.9912±.003 for the 1940 data. When the number of berries per cup and the mean diameter of a 3 per cent sample including the largest berries are plotted the curve is parallel to the curve in which the mean diameter of all berries is plotted. The correlation index for number of berries per cup and a 3 per cent sample including the large berries is 0.8816±.038 which means predictions may be made with a fair degree of reliability.

The foregoing analysis indicates a close relation between the different methods of measuring blueberry size and shows a method of predicting the number of berries per cup from a 3 per cent sample including the large berries.

A Comparison of Fungicidal Treatments for the Control of Botrytis Rot of Grapes in Storage

By W. T. Pentzer and W. R. Barger, *U. S. Department of Agriculture, Fresno, Calif.*

IN THE cold storage of vinifera grapes some microorganisms, notably *Botrytis* sp., make sufficient growth in a month or more at 32 degrees F to cause serious amounts of rot, calling for a supplemental treatment to control them. Considerable experimental work has been done to find a treatment that would be effective but non-injurious to the fruit and acceptable to food authorities. Sulphur dioxide has been found to be an effective aid in the storage of California grown grapes and has been widely used for this purpose during the past few years. Several other treatments have been applied to grapes especially in the South African districts where sulphur dioxide fumigation has not been acceptable because of excessive injury to their varieties. Some of these treatments have shown considerable promise. These and several other treatments were compared with sulphur dioxide fumigation in studies conducted at the Fresno Station in 1940–41.

Methods and Materials

The concentrations used and the methods of application followed were those found to be most satisfactory in previous investigations. Much of the experimental work with grapes has been done in South Africa with the South African pack in which about 10 one-pound bunches are wrapped individually with paper and packed with excelsior in a small wooden lug (16½ inches long, 11½ inches wide, 6 inches deep, inside measurements). A similar package was used in these trials. Emperor, the variety most commonly stored was selected for the test. The fruit, picked from the same vineyard, was carefully trimmed and mixed to reduce variability between lots. All of the fruit was then inoculated by dipping it in a suspension of *Botrytis sp.* spores and mycelia. It was dried quickly and then given experimental treatment and stored at 32 degrees F and 85 per cent relative humidity. Two lugs making up each lot were wrapped together in heavy paper to retard the loss of volatile materials added to the package. A description of the treatments employed follows:

Sulphur Dioxide:—Grapes were fumigated for 20 minutes with a concentration of about 1 per cent by volume at 70 degrees F. This treatment was similar to the usual application to commercial shipments of grapes in California. As soon as the fruit was fumigated, the bunches were wrapped, packed and stored.

Ortho-Phenyl Phenol:—Twenty grams of the chemical were dissolved in 200 grams of warm paraffin (55 degrees C) to give a concentration similar to that used by Rattray (2) in tests with South African grapes, although it was higher than concentrations used by Tomkins (4) in which the solvent was mineral oil instead of paraffin. Paper wraps (13½ by 16 inches) were dipped in the paraffin solution of ortho phenyl phenol, each wrap taking up about 5 grams of paraffin

containing ½ gram of the chemical.

Iodine-Potassium Iodide Wraps:—Wraps were soaked overnight in a solution of 15 grams each of iodine and potassium iodide in 1000 milliliters of 80 per cent ethyl alcohol. This concentration was equivalent to that used by DuPlessis (1) and contained slightly more iodine than Tomkin's mixture (3). The moist wraps were dried quickly and were then placed in tight containers until used several days later. Each wrap contained about 800 milligrams of the mixture. Bunches of grapes were enclosed in the treated wrap and were then covered by a second untreated one.

Formalin Spray:—About 8 milliliters of 6 per cent formalin solution were sprayed on the excelsior lining the box immediately before it was packed. An additional application of 2 milliliters was made to the excelsior covering the grapes. A treatment similar to this was found to be safe and effective by DuPlessis in tests conducted with South African grapes (1).

Ethyl Alcohol Dip — Waxed:—The grapes were dipped in 80 per cent ethyl alcohol and after being dried were dipped in a warm emulsion of wax consisting chiefly of carnauba wax. After the fruit was dried overnight it was packed and stored, one day later than the other lots.

Sodium Bisulphite Pellets:—A pellet made by folding 0.2 gram of powdered sodium metábisulphite in a small piece of towel paper was wrapped with each bunch of grapes.

Ammonium Carbonate Pellets:—Powdered ammonium carbonate was similarly applied as a pellet containing 0.2 gram for each bunch as it was wrapped, since other work had shown this to be a more effective way to apply the chemical than spraying a solution of it on the excelsior (1).

Ethylene Oxide Fumigation:—The fruit was fumigated 3½ hours in a concentration of gas applied at the rate of 4 pounds per 1000 cubic feet. Some fungicidal properties have been claimed for this fumigant, which is commonly used as an insecticide. The temperature during fumigation was about 70 degrees F.

Sodium Bisulphite Spray:—The excelsior used in packing the fruit was sprayed with 15 milliliters of 95 per cent ethyl alcohol containing 2 grams of powdered sodium metabisulphite.

Butyl Alcohol Spray:—A spray of 10 milliliters of 95 per cent butyl alcohol was applied to the excelsior.

Ethyl Alcohol Spray:—The excelsior packing material was sprayed with 10 milliliters of 95 per cent ethyl alcohol.

Methyl Bromide Fumigation:—Grapes were fumigated for 4 hours with a concentration of 4 pounds of methyl bromide per 1000 cubic feet at a temperature of about 70 degrees F. They were then packed and stored. This fumigant, commonly used as an insecticide has been credited with mild fungicidal properties.

Dichloramine-T Wraps:—This material, consisting of small white crystals that decompose on exposure to air with loss of chlorine, was applied as a wax suspension, 12 grams of the chemical being mixed with 200 grams of melted paraffin. The wraps, when dipped in this

mixture, took up about 5 grams of paraffin that contained about 0.3 grams of dichloramine-T. In tests made by Van der Plank and Rattray (6), diethyl-chloramine was applied to cotton plugs as a solution of 0.35 milliliter mixed with 0.65 milliliter of triacetin or in proportions of 0.18 to 0.82 milliliter respectively. When these treated plugs were wrapped with bunches of Emperor and Almeria grapes they gave good control of rot without injuring the fruit.

Results

Upon inspection after 10 weeks storage at 32 degrees, marked differences were noted in the amount of decay in the various lots. The average figure for the 18 to 20 bunches of each lot is given in Table I,

TABLE I—Comparison of Treatments for the Control of Botrytis Rot of Grapes in Cold Storage

Treatment	Decay After 10 Weeks Storage 32 Degrees (Per Cent)	Condition of Lot
None, not inoculated	38.6 ±4.10*	Normal except for decay
None, inoculated	35.8 ±4.00	Normal except for decay
Sulphur dioxide fumigation**	3.7 ±0.81	Slight pitting of fruit, not severe
Ortho phenyl phenol wraps**	7.3 ±1.43	About 95 per cent of fruit injured, brown color, cooked taste
Iodine—KI wraps**	9.6 ±1.64	Excelsior stained brown by iodine, fruit not injured
Formalin spray**	13.0 ±2.33	No injury, no odor of formalin
Ethyl alcohol dip, waxed**	22.8 ±2.64	Fruit unattractive, dull
Sodium bisulphite pellets***	23.1 ±2.82	Practically no injury
Ammonium carbonate pellets	28.3 ±2.96	Some bleaching of stems and fruit, not severe
Ethylene oxide fumigation	33.4 ±4.27	Severely injured, color gray-brown, "cooked" taste
Sodium bisulphite spray	35.9 ±3.43	No injury
Butyl alcohol spray	40.4 ±6.42	No injury
Ethyl alcohol spray†	46.0 ±2.26	No injury
Methyl bromide fumigation‡	54.7 ±3.93	No injury
Dichloramine T wraps‡	80.3 ±2.99	Distinct chlorine odor as bunch unwrapped, no injury

*Standard error.
**Treatment gave highly significant control of decay, odds greater than 99:1 that difference in decay attributable to treatment.
***Treatment gave fairly significant control of decay, odds of significance between 19:1 and 99:1.
†Fairly significant increase in decay (odds 19:1 to 99:1) attributed to treatment.
‡Significant increase in decay over untreated lots (odds better than 99:1).

together with any injury noticed after 4 days at 60 to 70 degrees F. That the fruit was well inoculated by natural infections is borne out by the large amount of decay in the uninoculated untreated lot.

The outstanding treatment was sulphur dioxide fumigation before packing. Next in effectiveness against *Botrytis* sp. was ortho phenyl phenol wraps, but severe injury to the color and flavor of the fruit ruled it out. Lower concentrations or reducing the vapor pressure of the chemical by mixing with it some other material as suggested by Tomkins (5) might give control without injury. Iodine-potassium iodide wraps gave fair control without injury to the appearance and flavor of the fruit, but the excelsior of the package was stained an unsightly brown color by the iodine. The formalin spray also gave fair control without injury. Fruit dipped in ethyl alcohol and then in

a wax emulsion had less decay than untreated fruit but it was dull and much less attractive. Sodium bisulphite pellets also gave some control of decay. Higher concentrations could have been used to good effect without injury.

The treatments that gave no significant control were ammonium carbonate pellets, ethylene oxide fumigation, sodium bisulphite spray, butyl alcohol spray, ethyl alcohol spray, methyl bromide fumigation and dichloramine wraps. The last three named treatments for some unexplained reason showed a significant increase in decay over the untreated check lots. Treatment with higher concentrations of some of these materials or with longer exposures to them might give better results.

Many of the materials used in these tests are more or less poisonous or toxic to human beings and have not been approved by food authorities and for this reason could not be recommended if they had proved to be effective. Other materials, such as sulphur dioxide, although not objectionable in the concentrations commonly attained in the fruit (10 to 20 parts per million) require care and supervision in their use.

Conclusion

Of a considerable number of volatile fungicides tried for the control of Botrytis rot of grapes in storage, sulphur dioxide fumigation consisting of 20 minutes exposure to 1 per cent concentration before the fruit was packed was the most effective.

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Red Leaf of Grapevines in California Prevented by Controlling Mites

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THE red leaf disease of grapes described by Butler (2) and also by Viala (4) has occurred periodically, since about 1900, in certain grape-producing areas of California. Losses of crop associated with it in the dry-wine producing districts north of San Francisco Bay have varied considerably with the season, in some years approaching 100 per cent in the worst affected areas.

In the red and black varieties, the leaves begin to turn red, usually between the primary veins, sometime in early- or midsummer. As the season advances, the color develops progressively in the leaf tissues until the entire leaf may become red or bronze-red with the exception of the large primary and occasionally secondary veins which for the most part remain green and are frequently bordered by narrow margins of green tissue. Parts of the leaf may dry and turn brown. With some seasonal variation the leaves usually begin to drop within a few weeks after the red color appears, and the vines may become mostly or entirely defoliated. Following early defoliation, a growth of new leaves develops toward the ends of the canes and on short laterals. The fruit of mildly affected vines often fails to mature properly; or, after the leaves in the center of the vine begin to drop, many of the clusters directly exposed to the sun may burn badly on the exposed sides. On severely affected vines the clusters wither from the tips; the berries progressively shrivel and dry up. Often this condition develops before the vines become defoliated.

In the white varieties, the leaves turn yellow instead of red, and areas on the leaf may dry out and turn brown. Leaves drop as do those of the red and black varieties; also the fruit is affected in a similar manner. The conditions described may involve only localized areas or entire vineyards.

Many varieties of grapes, and many other plants, develop red or bronze coloration in the leaves with the advent of autumn. Poor graft unions, and injuries such as partial or complete girdling by rodents, insects, or other means may cause unseasonable colorations in occasional vines; such occurrences can usually be diagnosed upon careful examination of affected vines and they are not a concern of the investigation here reported.

Vine Nutrition Tests

Butler (2) reported inconclusive results from experiments which involved spraying the vines with Bordeaux mixture and iron sulfate and soil applications of stable manure. Ravaz (3), and Bonnet (1) described a somewhat similar condition occurring in France as a result of potassium deficiency which could be remedied by the application of this material.

In view of the reports of Ravaz (3) and Bonnet (1), an examination

was made of the potassium status of the soils in vineyards which had red leaf. No correlation was found between the potassium concentration, either as exchangeable or as Neubauer potassium, and the incidence of the trouble. Field trial plots were laid out in Carignane, Sauvignon vert, Zinfandel, and Petite Sirah vineyards on four soil types in Sonoma County. Sixty vines, in two adjacent rows of 30, were given 3½ pounds of K_2SO_4 per vine per year in 1934, 1935, and 1936. In the Carignane vineyard an additional 20 vines received 5 pounds of K_2SO_4 per vine, hydraulically injected into the soil to a depth of 4 feet in April, 1934. Two pounds per vine were applied in a similar manner to 30 Petite Sirah vines to a depth of 2½ feet, and 3 pounds per vine to 28 Zinfandel vines to a depth of 3 feet. Observations were also made on other fertilizer plots laid out for different objectives. In no case observed during five seasons was there any improvement in the red leaf condition as the result of the application of fertilizer. Leaf analyses showed conclusively that additional potassium had been absorbed by the vines as a result of the addition of the fertilizer to the soil. It is evident, therefore, that this trouble is not one of potassium deficiency.

Since the trouble was observed chiefly in nonirrigated vineyards, small irrigation experiments were carried out on Zinfandel and Petite Sirah vines. The irrigation was not effective in preventing or correcting the trouble.

Trunks of Zinfandel vines which were known to have developed red leaf the previous five years were injected with salts of manganese, phosphorus, copper, magnesium, iron, zinc, and arsenic on May 1, 1937. By September, all of the vines injected with salts and the control vines had developed typical red leaf.

Experiments Involving Control of Mites

Zacharewicz (5) described a condition occurring in 1905 in Grand noir and Alicante Bouschet vineyards of France that appears to be very similar to that found in vines of these varieties in the present investigation, and which he attributed to a Tetranychus (mite) possibly a variety of *Tetranychus telarius*. The malady, in France, was said to be corrected when the mites were controlled by dusting the vines with a home-mixed pyrethrum preparation.

During the 1937 growing season, in the course of periodic observations made on the vines in the nutrition test plots a rather severe infestation of mites (*Tetranychus pacificus* Mc G.)[1] was discovered on July 22 in the Zinfandel and Petite Sirah.

On July 24, a block of 114 Petite Sirah vines and another of 96 Zinfandel vines were sprayed with Selocide[2] (1–400). To each 100 gallons of the spray mixture was added 5 pounds of dusting sulfur into which had been mixed 4 ounces of casein spreader. Approximately 98 per cent kill was obtained in both sprayed blocks. The population of mites

[1]Lamiman, J. F. (unpublished) had previously reported the presence of the Pacific mite on vines in the Ukiah area, about 20 miles north of the location of the test plots. Dr. Lamiman's aid in identifying the mites and in organizing and checking up on the control measures is gratefully acknowledged.

[2]A proprietary preparation containing selenium.

on unsprayed vines increased for another 10 days but by a month later had decreased to the point where but few mites could be found.

At the time the spray was applied, about 70 per cent of the leaves of the Petite Sirah vines had partially developed red coloring, and a few of the older leaves at the base of the canes had fallen. Following the spray, red leaf developed more rapidly in the vines of the sprayed plot than in the surrounding unsprayed vines. By the middle of September, the sprayed vines had dropped over 85 per cent of the old leaves and new leaves were beginning to form toward the end of the canes and on short laterals. Less than 50 per cent of the leaves had fallen from the unsprayed vines. However, by the last of September the unsprayed vines were nearly defoliated and new leaves were forming toward the tips of the canes. It appeared that the spray accentuated the development of red leaf in the Petite Sirah vines.

On the Zinfandel vines sprayed on the same day, less than 25 per cent of the leaves were partially red. Two weeks after the spray was applied, the sprayed vines were nearly as green as when sprayed, whereas the leaves of the unsprayed vines had noticeably reddened. By the middle of September, the sprayed Zinfandel vines were still fairly green and in good condition. The unsprayed vines were in the advanced stages of red leaf — all of the leaves had turned red, most of them had fallen from the vines, and new leaves were forming toward the tips of the canes. The fruit had not ripened and many of the clusters were sunburned or withering from the tips.

The sprays gave good control of the mites. To determine, however, whether it was the control of mites or the absorption of selenium by the vines from the spray that had resulted in the responses that were observed, 50 vines each of Zinfandel and Alicante Bouschet were pruned in February, 1938, and the freshly made pruning wounds were swabbed with a solution of selenious acid, 200 grams per liter. During the 1938 growing season, all of the treated vines developed typical red leaf.

In 1938 a series of spraying tests were made with Selocide, mixed as in 1937, and with a proprietary preparation of ammonium polysulfide. The latter was diluted 1 to 100, and to each 100 gallons of the spray mixture was added 5 pounds of dusting sulfur and 4 ounces of casein spreader.

The sprays were applied to plots of four rows of 10 vines each of Alicante Bouschet, Petite Sirah, and Zinfandel. Sets of plots were laid out in each of two separated blocks of Alicante Bouschet and Petite Sirah, which are hereafter referred to as block 1 and block 2 of the respective varieties. Only one set of Zinfandel plots was used. Each sprayed plot received only one spray application of one composition. An unsprayed plot was left adjoining each sprayed plot. One plot of each set was sprayed on May 25, another July 1, and another July 19.

Determination of the relative population of mites, *Tetranychus pacificus* Mc G., was made by choosing 20 leaves which showed symptoms of mite injury from a number of vines in each plot. Five circles, each 5 square centimeters in area, were stamped on the lower surface of each leaf and the mites occurring within these circles were counted.

TABLE I—OBSERVATIONS ON 1938 SPRAYING EXPERIMENTS

Date of Spraying	Treatment	Date: Jul 19	Aug 10	Sep 3	Sep 24
		Petite Sirah (Block 1)			
May 25	Check	Normal	A few red leaves	>75 per cent leaves red; <5 per cent defoliated	>75 per cent defoliated
May 25	Selocide	Normal	Normal	Normal	Normal
May 25	Ammonium Polysulfide	Normal	Normal	Normal	<5 per cent leaves red
July 1	Check	Normal	A few red leaves	50 per cent leaves red	>75 per cent defoliation
July 1	Selocide	Normal	Normal	Normal	Normal
July 1	Ammonium Polysulfide	Normal	Normal	Normal	Normal
July 19	Check	Normal	A few red leaves	75 per cent leaves red; 10 per cent defoliation; some injury to fruit	>75 per cent defoliation
July 19	Selocide	Normal	Normal	Normal	Normal
July 19	Ammonium Polysulfide	Normal	Normal	Normal	Normal
		Petite Sirah (Sprayed 1937)*			
July 19	Unsprayed 1937 and 1938	Normal	Normal	Normal	<50 per cent defoliated
July 19	Sprayed 1937 Unsprayed 1938	Normal	A few red leaves	75 per cent leaves red; no defoliation	Almost complete defoliation; new lateral growth started
July 19	Selocide 1937 and 1938	Normal	Normal	Normal	Normal
		Petite Sirah (Block 2)			
		Very little red leaf developed in any of the plots.			
		Zinfandel			
May 25	Check	A few red leaves	50 per cent leaves red; <5 per cent defoliation	>90 per cent leaves red; 25 per cent defoliation	>75 per cent defoliation
May 25	Selocide	Normal	Normal	Few leaves red only on canes extending into check plots	Leaves on inside vines green; <10 per cent leaves red on border rows
May 25	Ammonium Polysulfide	Normal	Normal	Few leaves red on vines adjoining check plots	25 per cent leaves red on inside rows; 75 per cent leaves red on border rows
July 1	Check	A few red leaves	50 per cent leaves red; <5 per cent defoliation	>90 per cent leaves red; 25 per cent defoliation	>75 per cent defoliation
July 1	Selocide	Normal	Normal	Normal	Normal
July 1	Ammonium Polysulfide	Normal	Normal	Few red leaves on vines adjoining check plots	Leaves on inside rows green; 10 per cent leaves red on border rows
July 19	Check	Normal	25 per cent leaves red	50 per cent leaves red; no defoliation	>50 per cent defoliation
July 19	Selocide	Normal	Normal	Normal	Normal
July 19	Ammonium Polysulfide	Normal	Normal	Normal	Normal
		Zinfandel (Sprayed 1937)*			
July 19	Sprayed 1937 Unsprayed 1938	A few red leaves	50 per cent leaves red; <5 per cent defoliation	>90 per cent leaves red; 25 per cent defoliation	>75 per cent defoliation
July 19	Selocide 1938	A few red leaves	A few red leaves	A few red leaves	A few red leaves

*See text for explanation.

Alicante Bouschet:—In the May 25 and July 1 plots of block 1, the mites did not develop in sufficient quantities to cause differences in the appearances of the sprayed and unsprayed plots until late in October. In the area containing the plot sprayed July 19, the unsprayed vines had developed red leaf to well-advanced stages by September 24, while the sprayed vines showed little or no characteristic injury and matured a normal crop of fruit.

In the Alicante Bouschet block 2, which was located about a mile from block 1, very few mites were found at any time during the season (Table II). By July 1, however, many leaves on more than 25 per cent

TABLE II—THE RELATIVE POPULATION OF MITES* *Tetranychus pacificus* IN SPRAYED AND UNSPRAYED PLOTS DURING 1938

Dates on Which Population Counts Were Made	Selocide Plots Date of Spraying			Ammonium Polysulfide Date of Spraying			Unsprayed Plots
	May 25	July 1	July 19	May 25	July 1	July 19	
				Alicante Bouschet Block 1			
June 14	—**	–	–	–	–	–	0
July 1	†	–	–	†	–	–	0.2
July 19	†	†	–	†	†	–	0.1
				Alicante Bouschet Block 2			
June 14	–	–	–	–	–	–	0
July 1	†	–	–	†	–	–	0
July 19	†	†	–	†	†	–	0.3
				Petite Sirah Block 1			
June 14	–	–	–	–	–	–	13.0
July 1	0	–	–	1.2	–	–	5.8
July 19	0	0	–	0.2	0.1	–	14.2
				Petite Sirah Block 2			
July 1	†	–		†	–		4.7
				Zinfandel			
June 14	–	–	–	–	–	–	11.5
July 1	0	–	–	0.9	–	–	18.9
July 19	0	0.1	–	2.7	2.7	–	62.4
August 26	21.4	0.2	0	60.5	64.8	2.5	162.9

*The relative population of mites was determined by collecting 20 leaves which showed evidence of mite injury from separate vines in the plot and counting the mites occurring in five circular areas, each covering 5 square centimeters which had been stamped on the underside of each leaf. The figures show the number of mites counted per leaf.

**—These plots had not been sprayed previous to the dates indicated. It was assumed that the mite population would correspond to that in the unsprayed plots.

†No counts were made in these plots because the mite populations were so low in the unsprayed plots.

of the vines had developed a considerable amount of bright red color in the tissues between the large veins. The development of red color continued throughout the remainder of the season and eventually involved nearly all of the primary and secondary veins as well as the tissues between them. The leaves of this variety normally become intensely red with a lowering of the temperature in the autumn. The coloration here described, however, developed in mid- and late-summer. Except for the premature coloring, the vines apparently grew normally, matured a good crop of fruit, and the leaves remained attached to the vines until frost occurred. This type of red coloring developed in vines in all of the sprayed and unsprayed plots. Since very few mites were found at any time during the season and these only on unsprayed vines (Table II),

it is believed that the symptoms in this particular block were not associated with injury of the mites *Tetranychus pacificus*, but were brought about by some other undetermined cause.

Petite Sirah:—As shown in Table I, the vines of all plots in block 1 remained normal, or nearly so, up to August 10. On September 3, however, the vines in all check plots had 50 to 75 per cent of their leaves showing typical red leaf injury, and by September 24 more than 75 per cent of the leaves had dropped. The sprayed vines remained normal throughout season except in the ammonium polysulfide plot of May 25 where less than 5 per cent of the leaves showed typical symptoms on September 24.

The plot of 114 vines sprayed with Selocide in 1937 was in this same block of vines. On July 19, 1938, forty of these vines were again sprayed with Selocide. The 74 unsprayed vines developed serious red leaf during 1938 showing there was no beneficial hold-over effect from sprays applied the previous year. The 40 sprayed vines remained healthy the entire season.

As previously stated, the Petite Sirah vines that were sprayed in 1937 after about 70 per cent of the leaves had begun to redden continued to develop red leaf and at a more rapid rate than did the unsprayd vines. In 1938 the sprays were applied before any appreciable red coloring had developed. It appears that if this type of red leaf has developed beyond a certain stage it will continue to develop even though the causative agent is removed.

Injury due to the feeding of mites and appearing as a yellowish discoloration, showed in the leaves far in advance of the development of red color. The relative mite populations in the various plots, based on counts, are shown in Table II. The population did not become very high even on the unsprayed vines; very few mites were found in either of the plots sprayed with ammonium polysulfide, and none were found in the plots sprayed with Selocide. Counts were not made after July 19 in these plots.

In block 2, the population of mites was very low prior to July 1 and no counts were made after that date. Very little red leaf developed in this area even in the unsprayed vines.

Zinfandel:—The red leaf was more severe in the May 25 and July 1 series of plots than in the July 19 series. The check vines of the first two series showed a few red leaves as early as July 19 and were more than 75 per cent defoliated by September 24. As shown in Table I, spraying with Selocide July 1 or July 19 held the vines in normal condition throughout the season; ammonium polysulfide was slightly less effective. The later sprayings were more effective than the earlier.

The relative population of mites is shown in Table II. The record of the counts made August 26 — the approximate peak of the population that season — show the differences most clearly. The relative population of the mites in the sprayed and unsprayed plots corresponds closely with the extent and degree of red leaf injury observed in the plots. No mites were found on the vines sprayed with Selocide on July 19 and very few on those sprayed July 1, but an appreciable number were found on those sprayed May 25. In the ammonium polysulfide

plots a few mites were found on the vines sprayed July 19 and a considerable number on those sprayed May 25 and July 1. The population was very high on the unsprayed vines. An examination of the vines on September 3 revealed that most of the mites had disappeared, hence no further counts were made.

Some of the vines sprayed in 1937 were again sprayed with Selocide on July 19, 1938. The remainder were left unsprayed in 1938. Vines sprayed in 1937 but left unsprayed in 1938 developed red leaf to the same degree as those never sprayed, while vines that were sprayed in 1937 and again in 1938 remained healthy throughout the season.

Vines that had been sprayed only in 1937, those sprayed in 1937 and again in 1938, and those never sprayed at all developed red leaf in 1939 to about the same degree. On July 13, 1939, some of the vines of each of these groups were sprayed with Selocide; they remained healthy throughout the season. These experiments show that no beneficial hold-over effect in following seasons was obtained from the sprayings.

Crop records were obtained from the Zinfandel plots in 1938. There were considerable fluctuations but no significant differences in the records of crop obtained from the sprayed and corresponding check plots. In 1938 serious leaf injury apparently occurred too late in the season to materially affect the development of the fruit.

Spraying tests made in another vineyard of Zinfandel showed mite infestation and red leaf injury to be much worse in 1939 on the vines that had been sprayed in 1938 and not again sprayed in 1939, than on vines that had received no spray treatment. The reason for this phenomenon was not determined. It may indicate, however, that the treatments killed off many or most of the natural enemies of the mites, thus allowing the mite population to build up to higher levels on vines sprayed the previous year than on unsprayed vines.

The materials employed in the mite-control tests were used strictly on an experimental basis. The results presented are in no wise to be construed as recommendations for commercial control.

Summary and Conclusions

A serious type of red leaf in black grape varieties is characterized by the development in early- or midsummer of red or bronze-red color in the leaf tissues between the primary veins and partial to complete defoliation by late summer or early autumn, usually followed by a weak development of new leaves toward the ends of the canes. The fruit often fails to mature, may sunburn, or beginning at the tips of the clusters the berries may shrivel and dry up, causing a partial to complete loss of crop.

No correlation could be established between the occurrence of this type of red leaf and the potassium content of the soils. Also heavy fertilization with potassium sulfate and trunk injections with magnesium, copper, iron, manganese, zinc, and arsenic salts failed to prevent its development. Neither did irrigation nor treatment of the dormant vines with selenium prevent it.

This form of red leaf is shown to be closely associated with mite

Tetranychus pacificus, Mc G. injury. It is prevented by controlling the mites if this is done before the injury becomes too far advanced, but killing the mites after the injury has caused red coloring to develop in the leaves failed to check its further development. Early summer spraying with Selocide and ammonium polysulfide was effective in controlling the mites. No beneficial effect from the sprays was observed to carry over into the following season.

Other forms of red leaf that occurred in the same vineyards in which these experiments were conducted are distinguished by bright red coloring of leaf tissues, including the larger veins. Vines thus affected failed to respond to any treatments.

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The Effect of Storage on the Carbohydrates of the Ebenezer Onion[1]

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THE reserve carbohydrates of the Ebenezer onion are practically all soluble and may amount to 65 per cent of the dry matter. Since sugars are the chief source of energy in respiration, this group of compounds should show the effect of unfavorable conditions of storage. The purpose of this investigation was to study the chemical changes in the soluble carbohydrate fraction of the Ebenezer onion effected by different conditions of storage and to ascertain the nature of the losses in storage.

EXPERIMENTATION

The onions were grown on Hadley very fine sandy loam type soil which received 2,200 pounds of a 5–10–5 fertilizer. They were harvested in the usual manner, screened to U. S. No. 1 size and placed in a sheltered area for further curing. Later they were sorted again, put in 50-pound hemp bags, and placed in storage. Storages were chosen which would represent varied conditions: Storage A, high temperatures and low relative humidity; C, low temperatures and high relative humidity; and B, conditions intermediate between A and C. The periods of storage were from about November 1 to February 15.

CHANGES IN THE SOLUBLE CARBOHYDRATE FRACTION IN STORAGE

Representative samples were obtained for analysis before and after storage. The total soluble sugars were separated into reducing and non-reducing sugars, and calculated as glucose and sucrose respectively.

The outstanding points shown in Table I are (a) the loss of total sugars varied from none to about 8 per cent; (b) the percentage loss was lowest for the coldest storage; and (c) the largest percentage of reducing sugars was found in the coldest storage.

TABLE I—TOTAL, REDUCING, AND NON-REDUCING SUGARS BEFORE AND AFTER STORAGE, AND PERCENTAGE LOSS OF TOTAL SUGARS IN STORAGE (DRY MATTER BASIS)

Storage	Total Soluble Sugars (Per Cent)	Reducing Sugars (Per Cent)	Non-Reducing Sugars (Per Cent)	Percentage Loss of Total Sugars
		1937		
Control*	65.38 ±0.24	5.24 ±0.15	60.14 ±0.33	—
A	60.07 ±0.19	12.92 ±0.20	47.15 ±0.19	8.12
B	61.59 ±0.38	16.20 ±0.20	45.39 ±0.57	5.80
C	62.13 ±0.29	20.95 ±0.20	41.18 ±0.38	4.97
		1938		
Control*	59.22 ±0.38	16.73 ±0.00	42.49 ±0.38	—
A	54.99 ±0.08	18.31 ±0.08	36.68 ±0.08	7.14
B	57.43 ±0.30	27.14 ±0.46	30.29 ±0.15	3.02
C	59.47 ±0.30	28.65 ±0.08	30.82 ±0.53	none

*Samples taken before storage.

[1]Contribution No. 385 of the Massachusetts Agricultural Experiment Station.

The losses were not large under the most adverse conditions employed. A maximum loss of about 8 per cent of total sugars was equivalent to about ½ pound of raw onions per 100 pounds.

The increase in the percentage of reducing sugars at low temperatures indicated that the conditions for contact between the enzyme and the substrate were favored (1). This further indicates that the Ebenezer onion may have a critical temperature range for the conversion of non-reducing sugars to reducing sugars.

The Nature of the Losses in Storage

In Table II it is shown that the largest percentage of marketable onions was obtained from the storage having the lowest mean temperature and the highest mean relative humidity; the largest percentage of sprouts was found in the storage having the highest mean temperature; decayed onions were negligible in all cases. These findings support the work of Cleaver (2), who found that the losses of Southport White and Yellow Globe onions in storage were caused chiefly by sprouting; also Wright, Lauritzen, and Whiteman (3) and Cleaver (2), whose investigations indicated that sprouting was due to high temperatures in storage.

TABLE II—Temperature, Relative Humidity, and Shrinkage in the Storages

Storage	Mean Temperature (Degree F)	Mean Relative Humidity (Per Cent)	Percentage Loss from—		
			Shrinkage	Decay	Sprouts
		1937			
A	58	35	24	—	32*
B	42	65	12	—	14*
C	34	85	6	—	4*
		1938			
A	57	35	18	1	57
B	42	55	10	—	33
C	33	85	5	1	11

*Decayed and sprouts combined.

The data presented indicate that the Ebenezer onion can withstand adverse conditions of storage for a considerable length of time without sprouting and apparently with the expenditure of very little energy. A large percentage of the onions which may sprout under adverse conditions can be saved by maintaining a temperature of about 32 degrees F in the storage. At this temperature level the percentage content of reducing sugars increases.

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A Preliminary Study of Some Water Relations in the Sweetpotato[1]

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KIMBROUGH (1) has published data which show that there is in general a high negative correlation between the moisture content of sweetpotatoes and their carbohydrate content. Unpublished data obtained by the author from several years work with sweetpotatoes varying widely in moisture and starch contents, show that there is a high negative correlation between the starch content and moisture content, and that there is no correlation between starch content and either total sugars, reducing sugars, or crude fiber.

Because it appears that starch in sweetpotatoes varies with the moisture, it is of interest to know whether any significant or important increase in starch content can be brought about by controlling the water supply available to the plants.

With this in view an experiment was started at State College in 1939 by planting single Triumph sprouts in each of 52 four-gallon glazed crocks, half of which contained 30 pounds of air dried Trinity clay soil and half 30 pounds of Oktibbeha clay loam soil. The Trinity soil is a very black and heavy clay soil having a wilting coefficient of 3.94 per cent. It had a pH of 5.7, and was high in calcium, magnesium, and nitrate nitrogen and medium, in phosphorus and potassium by rapid test determination (2). The Oktibbeha soil is a reddish yellow slightly sandy clay loam soil, having a wilting coefficient of 3.41 per cent. It had a pH of 5.0, and was medium in calcium and magnesium and low in nitrate nitrogen, phosphorus and potassium.

Preliminary tests had shown that sweetpotato plant growth could be maintained by daily or by weekly applications of water. Hence, after applying water to all pots to field capacity at planting and allowing them to stand for a week so that the plants would become established, two lots of five cultures each were chosen from each soil group and so arranged in rows by random, that there resulted a row of five cultures of each soil in duplicate plots for each of two watering treatments. A layer of sand 1 inch thick was placed on the top of the soil in all pots to reduce evaporation to a minimum and to aid penetration. Daily waterings were given to one plot of each soil group and weekly waterings to the other, the same quantity of water being applied at each watering. At first water was applied at the rate of 500 cubic centimeters to the culture, but this was increased as the weekly watered plants seemed to require it, or the daily watered seemed to be able to use it.

[1]Contribution from the Department of Horticulture, Mississippi Agricultural Experiment Station, State College, Mississippi. Published with the approval of the Director, Mississippi Agricultural Experiment Station. Paper No. 47, New Series, July 1941.

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Water application was increased to 750 cubic centimeters in 35 days, to 1 liter after 62 days and 1½ liters after 70 days, and was continued at this amount until harvest, 160 days after the different watering treatments were begun. The cultures were kept in a greenhouse, shaded during July and August so that the light intensity was reduced approximately one-half.

Results

Noticeable differences in appearance and rate of growth developed early between the two soils and between the two watering treatments. The leaves of the clay soil (Trinity) plants were darker green and the stems were less purplish colored than those of the clay loam soil (Oktibbeha) plants. The daily watered plants of both soils had "matured", that is, had practically stopped growth, and many leaves were yellowing at the time of harvest; while those weekly watered were

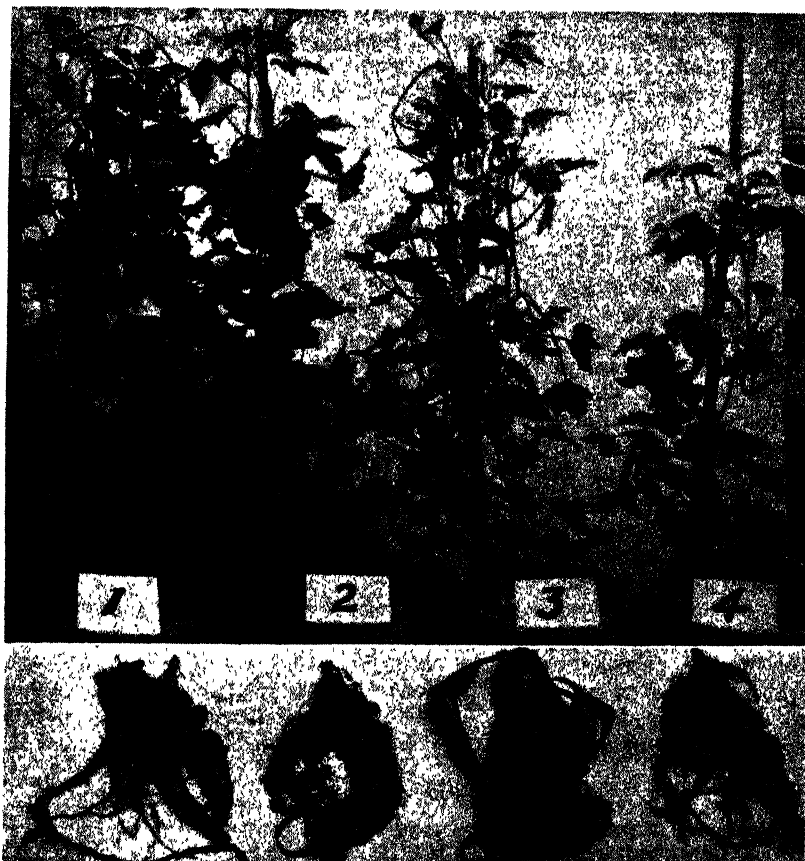

Fig. 1. Upper, plants on date of harvest; lower, roots from these plants. 1, clay soil, watered daily; 2, clay soil, watered weekly; 3, clay loam soil, watered daily; and 4, clay loam soil, watered weekly.

TABLE I—INFLUENCE OF SOIL MOISTURE ON THE GROWTH OF THE TRIUMPH SWEETPOTATO IN A POT EXPERIMENT

Soil	Watered	Mean Total Weight of Tops Per Plant (Grams)	Mean Single Leaf Area (Sq In)	Mean Total Weight of Root System Per Plant (Grams)	Mean Weight of Potatoes Per Plant (Grams)	Total Water Applied (Liters)
Clay......	Daily	749.6	11.92	496.6	381.5	180
Clay......	Weekly	328.1	14.78	35.4	0	26
Clay loam.	Daily	152.4	7.61	257.7	151.1	180
Clay loam.	Weekly	180.6	9.43	82.9	40.9	26

Difference required for significance:
Total weight of tops, 108.9 grams.
Total weight of roots, 97.6 grams.

continuing growth. The photographs of representative cultures of each treatment in Fig. 1, show that at harvest there were striking differences in appearance of plants and roots between the soils and watering treatments. The data in Table I show that highly significant differences occurred in mean total weight of tops from the two soils, and from the two watering treatments on the clay soil. The daily and weekly waterings did not make significant differences in growth of tops on the clay loam soil. Leaf size within treatments varied somewhat, but on the average the leaves were nearly twice as large on the plants growing in the clay soil as on those in clay loam soil. They were slightly but insignificantly larger on the plants watered weekly in both soils. The data show highly significant differences between the watering treatments of both soils in total root system weight, with daily watering greatly exceeding the weekly watering. There was no practical difference in the shape of roots from the various cultures (see lower part of Fig. 1). Watering the clay soil daily had a greater effect upon the growth of the root system than watering the clay loam soil daily. In the production of storage roots, the daily watering also made highly significant increases over the weekly watering. Also when the plants were watered daily the clay soil outyielded the clay loam soil. However, it is significant to note that not a single potato was made in the clay soil cultures watered weekly.

In Table II the data from analysis of the plant material show that there were no differences between the various cultures in moisture content of leaves or stems. In the potatoes, however, there were greater moisture percentages in those produced with weekly waterings of both soils, the content being slightly higher in the clay soil. In percentage

TABLE II—INFLUENCE OF SOIL MOISTURE ON CERTAIN CONSTITUENTS OF THE TRIUMPH SWEETPOTATO PLANT

Soil	Watered	Per Cent Moisture In			Per Cent Starch in Potatoes	Per Cent Total Sugars in Potatoes*	Per Cent Crude Fiber in Potatoes†
		Leaves	Stems	Potatoes			
Clay.........	Daily	80.06	79.98	77.26	13.29	3.05	4.05
Clay.........	Weekly	79.72	79.47	81.24	9.80	1.84	4.84
Clay loam....	Daily	80.38	79.77	73.42	17.08	2.50	3.46
Clay loam....	Weekly	80.68	79.77	80.66	11.25	1.84	4.33

Difference required for significance: In per cent of starch in potatoes, 2.98 per cent.
*Per cent of sugars in potatoes not significant.
†Per cent of crude fiber in potatoes not significant.

of starch, daily watering led significantly, and potatoes grown in the clay loam soil had a higher content of starch. In percentage of total sugars the differences were not significant but the daily watered cultures of each soil made more sugars in the potatoes than the weekly watered. The crude fiber content was approximately the same in all treatments.

The results presented here are not to be taken as conclusive, but they indicate that there are possibilities in influencing the moisture and carbohydrate contents of sweetpotatoes by irrigation. Further work on the problem is under way.

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Hot Water Treatment for Control of Nematodes in Sweet Potato Seed Roots[1]

By EARL F. BURK and GERTRUDE TENNYSON, *Oklahoma Agricultural Experiment Station, Stillwater, Okla.*

THE roots of most varieties of sweet potatoes are highly susceptible to nematodes, *Heteradera marioni* (Cornu) Goodey, which are widely distributed in the soils throughout Oklahoma. However, since mild nematode infections in sweet potato roots are not readily noticed, it is likely that hundreds of bushels of nematode infected roots are bedded for plant production each year, and that many of the infected plants which are sold or planted at home are set into fields that were previously free from nematodes.

Two practices are suggested to prevent the continued spread of the nematode disease by infected sweet potato roots. One is to use stem or vine cuttings to secure uninfected plants and the other is to kill the nematodes in the seed roots and thereby remove the source of infection. The first method cannot be conveniently and economically practiced in the northern part of the region in which nematodes are found in the field because the growing season usually is not sufficiently long to produce a sweet potato crop from field grown cuttings. It is for this reason that some means of treating the seed root seems most practical and desirable.

The hot water treatment for nematodes and certain other pests in bulbs and roots of nursery stock is now commonly used and therefore would seem possible for sweet potatoes.

In January, 1940, experimental work was started endeavoring to find satisfactory combinations of temperature and time of treatment as a means of killing the nematodes in the infected stored roots without destroying their value for slip production. The selected combinations

TABLE I—RESULTS OF HOT WATER TREATMENT OF SWEET POTATOES FOR CONTROL OF NEMATODE*

	Treatment 3		No. of Roots With Sprouts Emerging In			No. of Roots Without Growth In		
	Temperature	Time						
Plot	(Degrees F)	(Minutes)	Feb	Mar	Total	Feb	Mar	Total
1	110	240	2	2	4	5	1	6
2	110	360	0	1	1	5	4	9
3	114	120	4	3	7	3	0	3
4	114	240	3	2	5	3	2	5
5	118	120	1	1	2	6	2	8
6	118	180	0	1	1	8	1	9
7	122	60	0	1	1	9	0	9
8	122	120	0	1	1	8	1	9
9	126	20	2	3	5	5	0	5
10	126	40	1	1	2	7	1	8
11	126	60	0	0	0	10	0	10
12	128	5	5	1	6	3	1	4
13	128	10	3	4	7	3	0	3
14	Check	Check	6	2	8	1	0	1

*Each test plot consisted of 10 roots except plot No. 14.

[1]Recognition is given to Dr. H. B. Cordner of this station for suggestions in formulating and conducting this experiment.

for trial (see Table I) were based on treatments successfully used for other plant species.

For each treatment, uniform lots of 10 roots varying in size from 1¼ to 1½ inches in diameter were used. All roots in the tests were dipped in a solution of sodium hypochlorite (B-K powder) following the heat treatments. After treating, the sweet potatoes were planted individually in No. 10 tin cans filled with sterilized fine sand to test the viability of the treated roots and effectiveness of the treatments as controls for the nematodes. Several seeds of okra, tomatoes and snap beans (varieties Bountiful and Refugee No. 5) which are susceptible to nematodes were also planted in each can to serve as indicators of the presence of active nematodes. Nine untreated sweet potatoes were planted in sterile sand as checks. Three cans of sterilized sand were planted to the indicator crops alone as an additional check.

All cans were placed over an electric heating cable in a greenhouse which was thermostatically controlled to hold the temperature in the center of the cans at about 80 degrees F. The time that the slips emerged or the time that the root decayed was recorded.

On March 19, the test was concluded and the roots of the indicator plants were washed free of sand and observed for nematode infection. The okra and tomato plants were not found to be entirely satisfactory as indicator plants in this test because infections were too slow in developing on their roots.

The bean plants in six of the nine cans containing untreated sweet potatoes were infected with nematodes. The nematode galls grew rapidly and were easily distinguished from nodules. No infections were found on the bean plants that were grown in cans containing treated sweet potatoes. Neither were there any infected plants in the three check cans of sterilized sand. This indicated that all treatments were sufficient to kill the nematodes but the large number of rots resulting from some treatments indicate that they were too severe for the sweet potatoes. The results from this first test gave evidence that combinations of lower temperatures and longer periods of time might prove to be more favorable.

Investigations of the thermal death point of the nematode by Godfrey and Morita (1) indicate temperatures of about 118 degrees F for 10 minutes are necessary for the control of nematodes in the egg stage and 110 degrees F for 10 minutes for control of the larvae. Cobb (2) found in treating plants of 16 widely different orders of phanerogams with hot water varying from 116 to 118 degrees F for 10 to 30 minutes that *Heterodera marioni* (Cornu) Goodey, known to be in the plant roots before being treated were apparently exterminated.

Observations by the authors in January 1940 showed that some nematodes (eggs and larvae) were found as deep as ½ inch below the surface of the sweet potato root. There was evidence of three and four generations having been in the sweet potatoes, each successive generation penetrating deeper into the tissues. Roots examined in January 1941 showed a maximum penetration of the nematode to be ¼ inch deep. Field conditions during the summer of 1939 were much more favorable for nematode development than those of 1940.

With these facts in mind, a new approach to the problem was initiated in January 1941 in which heat penetration from water baths of different temperatures into the roots was investigated in order to determine the time required to heat the nematode bearing tissues of the sweet potato root to the critical temperatures necessary for the control of the nematodes. Thermocouples and a potentiometer were used for the temperature determinations.

Fig. 1 shows graphically the results secured from two such tests in which roots of 1¼ to 1½ inch diameter were treated in water baths at 116 and 126 degrees F. The time required for all treatments to reach the temperatures of 110 and 116 or 118 degrees F are given in Table II.

Table III gives the number of roots surviving treatments in water baths for different time intervals and at temperatures of 116, 119, 122, 126, and 132 degrees F.

From the above data, it appears that a temperature of 116 degrees is safest to use and that about

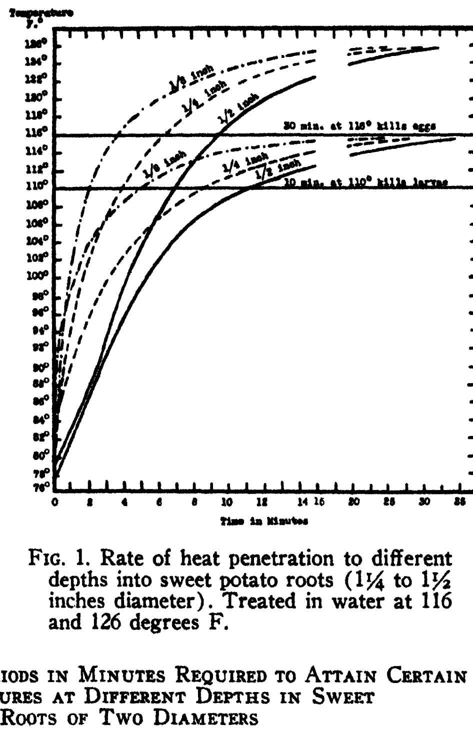

FIG. 1. Rate of heat penetration to different depths into sweet potato roots (1¼ to 1½ inches diameter). Treated in water at 116 and 126 degrees F.

TABLE II—TREATMENT PERIODS IN MINUTES REQUIRED TO ATTAIN CERTAIN CRITICAL TEMPERATURES AT DIFFERENT DEPTHS IN SWEET POTATO ROOTS OF TWO DIAMETERS

Temperature of Water Bath (Degrees F)	Depth in Root (Inches)	Large Roots 3 Inches Diameter		Small Roots 1¼ to 1½ Inches Diameter	
		110 Degrees*	116 Degrees*	110 Degrees	116 Degrees
116	⅛	7	40	6	25
	¼	12	50	9	30
	½	23	65	11	35
	¾	32	70	—	—
		110 Degrees	118 Degrees	110 Degrees	118 Degrees
122	⅛	4	13	6	
	¼	8	20	9	
	½	16	32	20	
	¾	25	36	25	
126	⅛	4	9	3	5
	¼	7	13	5	8
	½	13	23	7	11

*110 degrees considered to be critical for destruction of larva; 118 degrees for the eggs when temperature is maintained for a 10 minute period; 116 degrees for a 30 minute period also destroys larva.

TABLE III—DETERMINATION OF THERMAL DEATH POINT IN SWEET POTATOES BY COUNT OF VIABLE ROOTS AFTER TREATMENT AT DIFFERENT TEMPERATURES FOR VARIOUS TIME INTERVALS*

Bath Temperature (Degrees F)	No. of Replicates 5 Roots Each	Minutes Treated								
		15	25	30	35	40	45	50	55	60
116	6	—	—	—	—	29	30	29	28	28
119	6	—	—	—	—	20	19	20	12	9
122	6	—	—	21	13	17	17	6	7	—
126	6	—	7	4	1	0	—	0	—	0
132	6	13	—	0	0	0	0	—	—	—
		65	70	80	90	110	130	150	180	210
116	6	28	21	13	13	7	3	4	2	1
119	6	13	14	—	—	—	—	—	—	—
122	6	—	—	—	—	—	—	—	—	—
126	6	—	—	—	—	—	—	—	—	—
132	6	—	—	—	—	—	—	—	—	—

*A count of 30 indicates 100 per cent survival.

35 minutes would be required to heat the nematode bearing tissues of the potato to a depth of ½ inch. When 30 minutes is added to this to assure an effective control a total treatment period of 65 minutes is arrived at.

This treatment was checked in a test set up April 1, 1941, in which three half-bushel lots of nematode-infected roots with diameters of 1¼ to 1½ inches were treated at 116 degrees for 65 minutes. All roots were bedded in sterilized sand and interplanted with snap beans. Good plant production resulted from all lots with a very few of the roots decaying. Microscopic examination of the bean roots and the sweet potato roots at the end of the test failed to disclose any active nematodes. A duplicate test in which a treatment of 50 minutes at 119 degrees F was used gave practically as good results as that secured with 65 minutes at 116 degrees F, although on the basis of the earlier tests (Table III) a fairly high root mortality (about 33 per cent) might be expected from this treatment at 119 degrees.

From this study it appears that nematodes may be safely eliminated from sweet potato roots by heating at a temperature of 116 degrees or slightly higher. Temperatures of 122 degrees or higher are too injurious to the root tissues to be used with any degree of success and it appears that the roots are damaged to some extent by a 50 minute treatment at 119 degrees. Roots of the varieties Nancy Hall and Improved Porto Rico were used in these trials and there was some evidence that those of the latter variety were the more heat tolerant although additional tests must be conducted to establish this point.

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Preliminary Results on Delayed Harvest of Sweet-Potatoes for Industrial Purposes

By Geo. P. Hoffmann and J. M. Lutz, *U. S. Department of Agriculture, Meridian, Miss.*

SWEETPOTATO starch is manufactured for only a relatively short period each year because of the perishability of the crop, the costs of storage, and the conversion of starch to sugar in sweetpotatoes during ordinary storage. A longer operating season would reduce the overhead costs per unit of product as well as provide employment for a longer period of time. In most of the South, sweetpotatoes for market or storage are generally harvested before the first frost. Price (1) reported very high loss by decay during storage in sweetpotatoes dug 5 or 10 days after frost, and that the potatoes harvested 5 or more days after frost were of poor eating quality. Commercial growers in the vicinity of Meridian, Mississippi, generally finish harvesting their crop by October 25. The average date of the first killing frost in this locality is November 9.

Since sweetpotatoes for starch manufacture are not placed in storage but are used immediately after harvest, this investigation was undertaken to determine how late in the season sweetpotatoes for starch manufacture can be harvested without excessive losses from decay or starch conversion.

This preliminary report is based on observations made by the writers for the years 1936 to 1938. Extensive cooperative studies of this problem were begun in 1940 by the Bureau of Plant Industry and the Agricultural Experiment Stations of Texas and Louisiana. Results of the joint work will be reported later.

Methods

During the latter part of October when the regular crop of sweetpotatoes was harvested at the United States Horticultural Field Station, Meridian, Mississippi, a sufficient portion of the field was left to permit the harvesting of a 20-foot row of each variety for each treatment at each subsequent digging date in 1936 and 1937, and a 50-foot row in 1938. Preliminary observations in 1935 had indicated the possibilities of this method. The yields were approximately 1 pound per foot of row. At each digging the percentage of decay at time of digging was determined.

In 1937 and 1938, analysis of a representative 10-root sample of the Triumph variety was made at each digging for some of the treatments. The results are given in Table I. In sampling, a wedge-shaped section was taken from the sweetpotato so that it was representative of the entire root, both from end to end and from center to outside. These sections were rapidly sliced to a thickness of 1 millimeter with a mechanical slicer, a 50-gram sample was weighed out, and dropped into a pint jar containing sufficient 95 per cent alcohol to obtain a final concentration of 80 per cent, and boiled for 5 minutes. The samples were extracted with 80 per cent alcohol in a Soxhlet extraction appa-

TABLE I—EFFECT OF DELAYED DIGGING ON SWEET POTATOES

Date of Digging	Decay at Digging: Triumph (Per Cent)	Decay at Digging: Porto Rico (Per Cent)	Condition of Soil at Digging	Temperature Since Previous Digging: Soil—4 Inches Below Surface (Treatment No. 1): Mean (Degree F)	Soil—4 Inches Below Surface (Treatment No. 1): Minimum (Degree F)	Air—24 Inches Above Soil: Mean (Degree F)	Air—24 Inches Above Soil: Minimum (Degree F)	Rainfall 10 Days Before Digging (Inches)	Analysis of Triumphs at Digging, Treatment No. 1*: Dry Matter (Per Cent)	Solubles (Fresh Basis) (Per Cent)	Starch (Fresh Weight Basis) (Per Cent)	Starch (Dry Weight Basis) (Per Cent)	Decay After Curing and Storing Until March 11, 1938: Triumph (Per Cent)	Porto Rico (Per Cent)
						1937								
Oct 29	0.0	0.0	Fairly dry	—	—	—	—	0.30	33.23	4.37	23.36	70.3	3.1	7.6
Nov 8	1.8	0.0	Dry	59	43	62	35	0.00	29.22	4.51	19.96	68.3	18.2	7.6
Nov 18	1.1	0.7	Very wet	57	35	57	26	3.69	31.00	4.91	21.28	68.6	29.3	37.5
Nov 29	0.3	0.4	Moist	43	32	43	22	0.84	26.40	7.06	14.58	55.2	62.9	—
Dec 9	5.2	7.1	Moist and frozen on top	41	31	39	13	0.77	28.45	8.54	15.24	53.6	89.2	—
Dec 20	75.4	94.7	Moist	45	31	47	20	0.48	25.99	8.94	12.20	46.9	—	—
						1938								
Oct 25	0.0	0.0	Tillable	—	—	—	—	1.71	32.81	4.50	23.52	71.7	—	—
Nov 10	0.0	0.0	Wet	—	43	60	33	2.25	30.29	4.31	20.55	67.8	—	—
Nov 14	1.4	3.0	Moist	60	49	68	46	1.81	30.62	4.37	21.35	69.7	—	—
Nov 25	1.1	4.5	Wet	59	40	55	23	1.55	29.81	4.57	20.42	68.5	—	—
Dec 5	3.1	7.9	Tillable	45	36	44	17	0.12	29.44	6.28	18.65	63.3	—	—
Dec 15	3.7	2.5	Tillable	48	39	48	28	0.60	30.97	8.06	17.46	56.4	—	—
Dec 27	23.9	25.2	Very wet	45	38	47	28	2.84	28.84	9.61	14.51	50.3	—	—

*Vines undisturbed.

ratus. Solubles were determined by drying an aliquot of the alcohol-soluble portion to constant weight in a vacuum oven at 70 degrees C. Starch was determined by the difference method on the finely ground alcohol-insoluble material.

Soil and air temperatures in the sweetpotato field were taken with a soil-air thermograph checked at frequent intervals with a mercury thermometer. Soil temperatures were taken 4 inches below the surface of the soil, and air temperatures were taken in a standard weather shelter 24 inches above the soil.

Results in 1936

Preliminary results obtained with Nancy Hall sweetpotatoes showed that at Meridian, Mississippi, harvesting could be delayed for as long as 60 days after frost without appreciable loss by decay. The first frost in 1936 occurred November 5, four days earlier than the average. The mean temperatures for November and December were approximately normal. The minimum soil temperature during this period was 37 degrees F and the minimum air temperature was 28 degrees F. A baking test revealed no damage in potatoes harvested 30 days after frost. However, potatoes harvested 50 days after frost were very poor in quality, being characterized by a decided "frosted" flavor and failure to soften in baking.

Results in 1937

In 1937, 12 delayed-harvest treatments were made on the Triumph variety and five on the Porto Rico. Following are the treatments on Triumph:

1. Vines undisturbed.
2. Vines cut off at surface of soil before frost and left in place.
3. Same as No. 2 except vines cut after frost.
4. Same as No. 2 except vines left about 8 inches long.
5. Same as No. 4 except vines cut after frost.
6. Vines cut at surface of the ground before frost and raked over row as a mulch; after frost, row of potatoes covered with two furrows of soil.
7. Same as No. 6 except vines left 8 inches long.
8. Same as No. 6 except vines removed.
9. Same as No. 8 except vines left 8 inches long.
10. Same as No. 8 except vines cut after frost.
11. Same as No. 10 except vines left 8 inches long.
12. Vines undisturbed and water furrow plowed out in every other row with a middle buster.

Treatments Nos. 1, 6, 7, 8, and 9 were given to the Porto Rico variety also. The soil was Ruston sandy loam.

The results obtained in 1937 are summarized in the upper part of Table I. The first frost occurred on October 24. Air temperatures from October 29 to the November 19th digging were slightly above normal. From November 18 to December 9, the air temperatures were approximately 10 degrees F below normal, with a low of 13 degrees F on December 7. From December 9 to 20, temperatures were about normal.

Since there was no consistent difference resulting from the various treatments, the data on decay at digging and in storage were averaged for various treatments for each variety. The per cent decay at digging was not appreciable until December 9, 45 days after frost. The preceding digging 35 days after frost showed practically no decay and the later digging on December 20 showed almost complete loss by decay.

Since starch on a fresh weight basis is influenced to a considerable extent by the moisture content of the potatoes, starch on a dry weight basis and solubles are more accurate indices of physiological changes taking place. Loss in starch (on a dry weight basis) was not excessive through the November 18 digging. There was practically no difference between treatments Nos. 1 and 6 until this time. After this, starch loss was slightly less in treatment No. 6 where the potatoes were covered by throwing up the soil. Minimum temperatures at the level of the potatoes were approximately two degrees F higher in treatment No. 6 than in treatment No. 1.

Decay in storage increased with increasing delay in digging. This is further evidence that although potatoes harvested after frost may appear sound when harvested, danger of decay in storage is high.

Baking tests were made immediately after digging at each digging date. No "frost injury" was apparent until November 29 when there was slight injury. By December 9, the injury was severe.

Results in 1938

In 1938, seven delayed harvest treatments were made on both the Triumph and Porto Rico varieties. Treatments Nos. 1, 2, 8, 9, 10, and 11, listed in the 1937 experiments were used, as well as treatment No. 13 which consisted in leaving the vines uncut and covering the row of potatoes with two furrows of soil after frost.

The results obtained in 1938 are summarized in the lower part of Table I. A light frost which killed part of the vines occurred October 24 and a heavier frost on November 10 killed the remainder. Air temperatures were about average or above until November 25. The period between the November 25 and December 5 diggings was characterized by temperatures about 6 degrees F below normal with a low of 17 degrees F on November 28. Temperatures between December 5 and 27 were about normal.

As in the previous year, there was no consistent difference between the various treatments so the decay at time of digging for the various treatments was averaged. The percentage of decay was rather variable but generally not excessive until the December 27 digging when about one fourth of the potatoes were decayed. Starch analyses were made at each digging date for treatments Nos. 1, 9, and 11. Since there was no consistent difference in the percentage starch for the three different treatments, only the data for treatment No. 1 are presented. As shown in Table I there was no appreciable loss in starch on a dry weight basis through the November 25 digging. Baking tests showed no "frost injury" until December 15 when a very slight amount was present. On December 27 the potatoes appeared definitely "frosted" when baked.

SUMMARY

In a normal year it appears practicable to harvest sweetpotatoes for immediate starch manufacture as late as November 20 to 30, a month later than the usual harvesting date for sweetpotatoes in the vicinity of Meridian, Mississippi. In a milder climate, the delay could doubtless be longer. However, such late harvested roots cannot be stored with any consistent degree of success because of danger of decay. These results suggest that if the delay is too prolonged, serious loss of starch may occur even though the roots may appear sound at harvest. More comprehensive cooperative studies are in progress to determine, in several different localities, how long after frost the harvest can be extended without undue loss from decay of roots or loss in starch content.

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Addendum

Mr. W. R. Richee, Manager of the Laurel, Mississippi, Starch Plant has supplied the authors through correspondence and personal conversation, the following information regarding his experience with delayed harvesting of sweetpotatoes for starch manufacture. During the 1939 season, the first killing frost at Laurel occurred on November 18. The starch factory operated continuously until January 14, 1940, using potatoes the harvesting of which was delayed until just before grinding. The starch content of the potatoes in the early part of January of that year was over 20 per cent. The starch content of fresh potatoes at the Laurel Starch Plant on November 28, 1940, 12 days after a hard freeze, was 23.96 per cent. Mr. Richee also stated that the quality and manufacturing yield of sound sweetpotatoes is not adversely influenced by the delay in harvest. He believes that the temperature and moisture conditions after frost should affect the length of possible delay. It appears that the delay in the vicinity of Laurel could be somewhat longer than that around Meridian, Mississippi.

The Efficient Use of Nitrogen in Tomato Culture

By JACKSON B. HESTER, *Riverton, N. J.*

COMMERCIAL fertilizers play an important role in tomato culture and nitrogen long has remained the most expensive plant nutrient that the grower has had to purchase. The amount of nitrogen used by certain of the growers in New Jersey varied from practically none to over 140 pounds (5) to the acre in 1940. Likewise a tremendous variation in yield (from less than 5 to nearly 15 tons per acre) also was found to occur where different growers used an equal amount of nitrogen, namely 75 pounds to the acre. It must be admitted, however, that many factors other than the nitrogen used, influenced the yield and perhaps these factors influenced the yield, in many cases, even more than the amount of nitrogen applied. Since this is true, the question of the efficient use of nitrogen is important. Furthermore, it is known that an over-stimulated plant will be vegetative and not given to fruit production (6). Therefore the amount of nitrogen used and the method of application of this nitrogen to the soil is of utmost importance.

While the requirements of 3,000 tomato plants are known to be about 3 pounds of nitrogen during the first month of growth, 27 pounds during the second and 70 pounds during the third month (1); the difficulty of meeting these requirements in all soils under varying climatic conditions remains a perplexing problem. Studies of the nitrate and ammonia content of the various soils reveal a tremendous difference from week to week and from soil type to soil type.

Fertile soils are known to produce abundantly and the fertility of an agricultural soil is determined largely by the organic matter content. The primary function of the organic matter in the soil is to furnish nitrogen to the plant. This nitrogen is available only to the plant when it is broken down by soil micro-organisms to ammonia and nitrate nitrogen. This breakdown is slow in cold weather, but becomes more rapid as the summer season advances. Therefore under fertile soil conditions the plant is furnished available nitrogen somewhat as the requirements of the plant become greater. Consequently it is logical that the best use of nitrogen would be to supply it to the plant as needed.

The practice of many commercial growers is to place a large part of the nitrogen in the row before planting, either by mixing with the soil, by double bands on either side of the plant, or one continuous band under the plant.

In 1939, some 13 replicated experiments were conducted in New Jersey and Pennsylvania using 1,000 and 750 pounds per acre, respectively, of commercial fertilizer mixed with the soil in the row before planting. Using the fertilizer analyses x–16–8 and 0, 4 and 8 per cent nitrogen in the formula, an average of all of the yields was as follows: 11.01, 10.30, and 9.66 tons per acre (3); also see results by Parker (7). In repeating a part of the experiments in 1940 somewhat similar results were obtained. Although the above depressed yields were obtained, other systems of nitrogen fertilization gave rather spectacular results.

Reasoning that a soil with an organic matter content of 1.5 per cent would contain approximately 15 tons of humus to the acre or about 1,500 pounds of nitrogen; and if 3 to 5 per cent of this nitrogen is changed to nitrate nitrogen during the summer, some 45 to 75 pounds of nitrogen would be available to the crop. Of course crop debris and manure of various kinds would alter these figures one way or another. Therefore on the basis of this reasoning various experiments with nitrogen were started in 1939 and 1940 (2, 3, 4).

METHODS OF APPLICATION

One experiment was conducted upon a Sassafras fine sandy loam using a number of systems of fertilization, namely (a) 1,500 pounds per acre of 5–10–10 mixed with the soil in the row before planting; (b) 1,500 pounds per acre of 5–10–10 broadcast and plowed down; and (c) 750 pounds per acre of 0–20–0 mixed with the soil in the row before planting and 750 pounds of 10–0–20 used as two sidedressings about two and seven weeks after planting. The plats consisted of four rows 20 plants long, each treatment being repeated four times. The plants were all set with transplanting solution (3). The center two rows were used for records. Each 2 weeks throughout the season four plants from the guard rows were harvested, dried and analyzed for nitrogen. The results of these analyses are given in Table I. Mixing all of the fertilizer with the soil in the row was not as disastrous in 1940 as in former years because of a long wet spell following the fertilizer application and also another following transplanting. However, on this soil type the use of the nitrogen and potash in two sidedressings was the most efficient method. The plants in the row application of fertilizer appeared to be over-vegetative and the amount of nitrogen in the foliage appeared to substantiate these observations.

PLOWING THE NITROGEN DOWN

Two other experiments were set up in which various amounts of cyanamid, namely none, 100, 200, 400, and 600 pounds per acre (Table

TABLE I—INFLUENCE OF METHODS OF APPLYING FERTILIZER UPON THE NITROGEN COMPOSITION OF THE PLANT

Date Sampled	Nitrogen Absorbed: May 28	June 11	June 25	July 9	August 6	August 21	Total Yield Per Acre (Tons)
			M. E. per Gram				
1	2.92	3.06	2.66	2.28	1.50	1.89	10.6
2	1.80	1.90	1.58	1.79	1.47	1.45	11.6
3	1.74	2.42	3.14	2.02	1.64	1.81	13.4
			Pounds per 3000 Plants				
1	0.33	3.52	21.02	59.00	82.69	77.01	—
2	0.16	0.83	7.26	55.06	70.54	73.34	—
3	0.20	1.53	9.83	43.18	75.06	76.68	—

All plats set with transplanting solution.
1. 1500 pounds per acre of 5–10–10 in row.
2. 1500 pounds per acre of 5–10–10 plowed down.
3. 750 pounds per acre of 0–20–0 in row and 750 pounds of 10–0–20 as a sidedressing.

TABLE II—INFLUENCE OF NITROGEN UPON YIELD

Cyanamid (Pounds Per Acre)	Materials Used as Sidedressers†									
	0-0-50*		0-0-50		10-10-15		10-0-15		10-0-30	
	A	B	A	B	A	B	A	B	A	B
None	12.2	11.6	15.4	11.5	10.7	12.1	12.0	11.4	11.4	13.0
100	15.7	—	14.0	—	13.0	—	12.7	—	11.0	—
200	13.7	11.9	16.7	11.1	12.1	11.6	11.3	10.5	11.3	12.2
400	12.5	10.6	13.0	11.0	10.4	11.4	12.7	10.6	13.1	12.2
600	14.2	11.3	14.3	11.3	13.2	12.4	14.2	10.8	12.9	11.5

*Plowed down with cyanamid.
†300 pounds of 0-0-50 and 750 pounds of 10-10-15, 10-0-15, and 10-0-30 per acre in two sidedressings; 1,000 pounds of superphosphate in the row.

II) were broadcast previous to plowing and planting. These experiments were located upon a Collington fine sand (A) and a Sassafras sandy loam (B). The previous crop on the Collington was sweet corn and on the Sassafras, lima beans. One thousand pounds of superphosphate were mixed with the soil in the row previous to planting. Nitrate nitrogen determinations were made upon the soil each two weeks during the growing season. The 600-pound application of cyanamid had a slight sterilizing effect upon the soil and less nitrate nitrogen was found there than on the 400-pound application. It is noted that this 600-pound application gave a larger yield than the 400-pound application on both soils. The 200-pound application of cyanamid plowed down gave the largest yield on soil A and no stimulation of yield from nitrogen was observed on soil B. Consequently under the conditions of these experiments 200 pounds of nitrogen plowed down was adequate nitrogen in 1940. However, 1940 was a very peculiar season in that the spring was late, cold and wet; the summer had 13 days of abnormally hot dry weather with the remainder of the time being subnormal temperature; and the fall was cold and wet.

Five experiments in four states in the Middle West indicated that broadcast application of various sources of nitrogen was the most efficient system of applying nitrogen of all the systems experimented with. Three experiments conducted in Pennsylvania indicated also that broadcasting the nitrogen and plowing it down was more efficient than row or side applications. These experiments can not be summarized here because of lack of space. However, from the information thus accumulated it appears that plowing the nitrogen down before planting on heavy soils or using a greater portion of it as a sidedressing on light soils is more efficient than row application. This applies to cases where sufficient fertilizer is used to really influence the crop.

THE INFLUENCE OF NITROGEN FERTILIZERS UPON QUALITY

Twenty-five pounds of fruit were selected from each series of plats at the largest picking to ascertain if nitrogen fertilization influenced the quality of the crop. Dr. E. F. Kohman processed and canned the pulp from the tomatoes. The chemical analyses shown in Table III indicate no significant differences in composition of the tomatoes outside of a slight increase in the nitrogen content. Undoubtedly had the

TABLE III—INFLUENCE OF NITROGEN FERTILIZERS UPON THE QUALITY OF TOMATO PULP

Treatment	Total Yield per Acre (Tons)	Color	Grams per Liter			Mg per Liter Ascorbic Acid	M.E. per Liter					pH	
			Total Solids	Sugars	Titratable Acids		Ca	Mg	N	P	K	Plain	NaCl
No fertilizer	7.4	A–	64.5	41.9	46	285	3 2	1.2	102	11	62	4.4	4.2
	3.2	C	56.5	32.2	54	219	4.2	1.4	124	10	38	4.3	4.2
	6.7	C–	52.8	29.0	57	224	3.2	1.0	117	10	40	4.3	4.1
	7.3	B	52.8	25 6	70	200	4.3	4.1	132	9	46	4.2	4.0
Mean	6 1	B–	56.7	32.2	57	232	3.7	1.9	119	10	46	4.3	4.2
0–16–8	9.1	A–	65.5	38.1	63	280	3.4	1.5	110	12	67	4.3	4.2
	8.0	B–	59 3	35.8	56	239	3.6	1.5	113	10	44	4.3	4.1
	14.7	C	54.3	29.3	62	223	3.2	1.1	125	11	50	4.2	4.0
	10.1	B–	52.5	24.3	77	196	4.4	1.0	128	9	49	4.1	4.0
Mean	10.5	B–	57.9	31.9	64	235	3.7	1.3	119	10	52	4.2	4.1
4–16–8	7.9	A–	66.5	39.2	63	278	3.1	1.3	118	11	61	4.4	4.3
	9.8	B–	59.3	37.1	54	234	3.6	1.3	121	10	52	4.3	4.1
	12.7	B–	55.0	29.1	65	226	3.8	1.2	122	10	49	4.2	4.0
	8.4	B	52 5	25.1	72	197	4.3	2.7	128	9	56	4.2	4.0
Mean	9.7	B–	58.3	32.6	63	234	3.7	1.6	122	10	54	4.3	4.1
8–16–8	9.7	B	69.0	42.7	58	286	3.2	1 2	120	11	70	4.4	4.3
	7.7	B	57.3	32 6	56	213	3.2	1.1	128	10	44	4.3	4.1
	12 2	C–	53.8	27.9	65	209	3.6	1.3	132	10	47	4.2	4.0
Mean	9 9	B	60.0	34.4	59	236	3.3	1.2	127	11	54	4.3	4.1

available nitrogen in the soil been low enough to have materially lowered crop yield a more phenomenal difference would have been found.

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The F_1 Combining Ability of Certain Tomato Varieties[1] [2]

By RUSSELL E. LARSON, *University of Minnesota, St. Paul, Minn.*

ABSTRACT

This material will be published in full elsewhere.

FIRST generation hybrids between relatively new varieties and unnamed strains of tomatoes were grown in a randomized block test to determine their ability to develop such desirable characters as earliness, yield, size of fruit, shape of fruit, and combinations of these characters. Favorable combinations of characters developed by the F_1 are of special interest since it is difficult, if not impossible, to combine characters such as extreme earliness, smooth fruit, and large fruit size in homozygous material.

As other workers have shown, earliness, size of fruit, and shape of fruit are intermediately inherited. This is in agreement with results of this test. Highly significant correlation coefficients were obtained in each case between the means of the parents and the F_1 hybrid. Regression equations were computed from the data making it possible to predict, with relative accuracy, the behavior of the hybrids.

TABLE I—THE MEAN YIELD, EARLINESS, SIZE, AND SHAPE OF 19 F_1 TOMATO HYBRIDS AND THEIR PARENTS

Number	Hybrids and Varieties	Total Yield (Tons Per Acre)	Earliness (Days to Ripening)	Fruit Size (Ounces)	Fruit Shape Index
1	3-38 × Valiant	32.67	114	4.99	.850
2	3-38 × Earliana	29.57	109	3.84	.820
3	3-38 × 11-38	23.47	111	4.10	.818
4	3-38 × Allred	23.03	113	3.80	.791
5	3-38 × 6-38	23.17	110	4.13	.805
6	11-38 × Valiant	28.80	120	6.59	.810
7	11-38 × Allred	21.26	114	4.94	.705
8	11-38 × Earliana	27.32	111	4.88	.815
9	Valiant × 10-38	24.44	113	4.19	.851
10	Valiant × Allred	26.63	119	5.22	.783
11	Valiant × Earliana	25.47	119	5.20	.817
12	Earliana × Sc. Dawn	27.61	112	5.12	.806
13	Earliana × 10-38	24.26	107	3.15	.846
14	10-38 × Allred	19.98	106	2.67	.820
15	10-38 × 6-38	26.90	105	2.55	.858
16	Sc. Dawn × 6-38	33.21	114	4.45	.819
17	6-38 × 11-38	27.87	115	4.80	.813
18	6-38 × Valiant	24.24	107	3.57	.802
19	Redcap × Allred	26.05	113	4.83	.765
20	11-38	27.35	110	4.37	.848
21	10-38	19.49	105	2.29	.871
22	Earliana	28.04	109	4.54	.772
23	Valiant	23.39	119	6.77	.839
24	Allred	19.17	120	5.01	.699
25	Sc. Dawn	25.22	120	6.82	.861
26	Redcap	21.88	119	6.21	.788
27	6-38	20.75	106	3.57	.712
28	3-38	20.53	110	3.73	.801
	Significant differences	5.409	3.62	0.65	0.04

[1]Paper No. 1885 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

[2]Completion of certain parts of this paper was made possible by personnel of the Works Projects Administration Official Project 65-1-71-140. Subproject 408. Sponsor: University of Minnesota.

With regard to yield, it is evident that the factors for greater yield are dominant in most F_1 hybrids, but the complementary effect of genes for yield, in several crosses, produces an F_1 that is higher yielding than either parent. It is therefore impossible to obtain a significant correlation between the dominant higher yielding parent and the F_1 since there is no uniform change of one variable with the other.

Table I indicates the increases in yield of several F_1 hybrids over their parents. None of the parents of the highest yielding crosses were high in productivity; therefore, it is apparent that for yield the testing of combinations must be emphasized rather than making predictions from the yield records of the parents. Table I also presents the means of the other three characters for all the hybrids and varieties tested. It is clear that no one hybrid or variety has a perfect combination of all four characters. However, among the small number of crosses tested, there are indications that certain hybrids develop combinations of characters that are superior to their parents or any other self pollinated variety in this test. Crosses 1 and 16 appear to be superior in yielding ability and develop earliness, shape of fruit, and size of fruit equal to the better inbred varieties.

In consideration of the transmission of yielding ability of different parents, there were six strains that entered into at least five different combinations each. These were Earliana, Valiant, Allred, 3–38, 11–38, and 6–38. The mean progeny yields of each parent based on five combinations for each are 26.85, 27.60, 23.39, 26.38, 25.74, and 27.08 tons per acre respectively. It seems that none of the strains were consistently a superior parent when used in a number of combinations although Valiant may be considered somewhat superior to Allred. The data would be more conclusive if the combinations were more numerous for each of the parents being compared, but again, there is no definite indication that general prediction can be made until the individual combinations are grown.

The Interactions Between Variety, Spacing, and Staking of Tomato Plants[1]

By T. M. CURRENCE, *University of Minnesota, St. Paul, Minn.*

THE objective was to determine the most suitable planting distances for three distinct types of tomato varieties, namely dwarf, self-pruning, and standard. The test was also arranged to include three treatments on staking and pruning. These were (a) untreated, (b) staked but not pruned, and (c) staked and pruned to three stems. The spacings were 1.0, 1.5, 2.0, 3.0, and 4.0 feet between plants in rows that were 4 feet apart.

The split plot design is adapted for tests where the relative importance of different factors under test is not the same. In this instance the interactions were emphasized since they comprise the comparisons to determine the more productive spacings and treatments for the three different types and the comparisons of the different spacings for the three treatments. The triple interaction of varieties, spacings, and treatments provides comparisons of the varieties' response to treatments at the different spacings. However, this interaction was not found to be significant for early yield, total yield, or fruit size.

The five spacings were randomized in long rows across each block, the rows being 108 feet long. Thus the spacing blocks were five rows wide and 108 feet long. The three varieties were planted at random in 36-foot plots cutting across the five spacing rows. Treatments were then randomized across the spacings and within each variety. Five replicates or blocks were grown. The records were analyzed for early yield, total yield, and fruit size.

Harvesting began on August 5, and ended September 26, with 15 pickings for the season. The early yields were made up of the first five of the pickings covering dates from August 5 to August 19. The fruits were graded into marketable and culls. The latter were mostly cracked fruits, or were too small in size to be marketed as fresh tomatoes.

For showing all the comparisons for early marketable yields in tons per acre Table I is presented. The analysis of variance indicates significant differences for spacings and for treatment x variety interaction. The spacing means are shown in the right hand column of the table and the interaction treatment x variety means are the bottom row of the table. The spacing of one foot between plants was the most productive of early tonnage. The early yield is significantly greater than that of other spacings and is 3.8 times the yield of the 4-foot spacing. The interaction means are of interest due to the different responses of the standard plant variety, Break O' Day, and the determinate growth habit type, Pritchard. The former was benefited by the pruning treatment whereas there is a suggestion that it was detrimental to Pritchard. The

[1]Journal Series Paper No. 1903 of the Minnesota Agricultural Experiment Station. Completion of certain parts of the work presented in this paper was made possible by the personnel of the Work Projects Administration, Official Project No. 165-1-71-124. Sponsor: University of Minnesota.

TABLE I—EARLY YIELDS IN TONS MARKETABLE FRUIT PER ACRE OF THREE TYPES OF TRAINING OF TOMATO PLANTS USED ON THREE VARIETIES AT FIVE DIFFERENT SPACINGS IN 4-FOOT ROWS

Spacing	Untreated			Staked not Pruned			Staked and Pruned to Three Stems			Mean*
	Dwarf Champ	Break O'Day	Pritchard	Dwarf Champ	Break O'Day	Pritchard	Dwarf Champ	Break O'Day	Pritchard	
1.0	1.53	2.44	1.59	1.50	1.48	3.55	1.32	2.85	2.50	2.80
1.5	1.18	1.43	1.20	1.17	2.18	1.75	1.11	2.30	1.66	1.55
2.0	0.97	2.15	1.93	1.03	1.29	1.56	1.22	2.25	1.53	1.55
3.0	0.75	1.15	1.28	0.56	1.02	1.93	0.72	2.45	1.59	1.27
4.0	0.41	0.89	1.08	0.57	0.72	0.75	0.54	0.70	0.94	0.73
Mean†	0.97	1.61	1.42	0 97	1.34	1.91	0.98	2.11	1.63	

*Significant difference = 1.148.
†Significant difference = 1.001.

difference may be associated with the different types of growth of the two varieties.

The total yields in marketable fruit are presented in Table II. No

TABLE II—TOTAL YIELDS IN TONS MARKETABLE FRUIT PER ACRE OF THREE TYPES OF TRAINING OF TOMATO PLANTS USED ON THREE VARIETIES AT FIVE DIFFERENT SPACINGS IN 4-FOOT ROWS

Spacing	Untreated			Staked not Pruned			Staked and Pruned to Three Stems			Mean*
	Dwarf Champ	Break O'Day	Pritchard	Dwarf Champ	Break O'Day	Pritchard	Dwarf Champ	Break O'Day	Pritchard	
1.0	14.51	22.34	21.56	14.05	19.37	23.82	11.44	21.36	18.22	18.52
1.5	12.13	20.55	18.98	13.24	21.48	19.44	9.45	17.28	13.48	16.23
2.0	11.74	20.16	19.50	12.15	17.93	18.92	8.03	14.26	14.90	15.29
3.0	9.98	18.48	21.76	10.65	17.76	18.35	5.45	11.12	11.41	13.88
4.0	7.01	15.94	14.72	8.02	12.55	11.71	3.61	8.39	8.19	10.02
Mean	11.07	19.49	19.30	11.62	17.82	18.45	7.60	14.48	13.24	

*Significant difference = 4.821.

interaction was significant for these yields. The total yields of all varieties were uniformly reduced by the pruning treatment and the staking without pruning was approximately equal to the yields of the untreated plots. Also the closer spacings rather uniformly increased the yields of all varieties and all treatments. Each of the three main effects, varieties, spacings, and treatments, have highly significant F values for total yields and Table III is shown to present the variety

TABLE III—TOTAL YIELDS IN TONS MARKETABLE FRUIT PER ACRE FOR THREE TYPES OF TRAINING OF TOMATO PLANTS USED ON THREE VARIETIES

Variety	Untreated	Staked	Staked and Pruned	Mean*
Dwarf Champion......	11.07	11.62	7.60	10.10
Break O'Day.........	19.49	17.82	14.48	17.26
Pritchard............	19.30	18.45	13.24	16.70
Mean†..............	16.62	15.96	11.77	

*Significant difference = 4.092.
†Significant difference = 2.023

and treatment means. The dwarf champion variety was found to produce a low yield and the combination of pruning and staking reduced the yields by more than four tons per acre.

A consideration of fruit size is shown in Table IV. The means are

TABLE IV—SIZE OF FRUIT IN OUNCES OF THREE VARIETIES OF TOMATOES AT FIVE DIFFERENT SPACINGS IN 4-FOOT ROWS AND THREE TYPES OF PLANT TRAINING

Feet Between Plants in 4-Ft Rows	Variety			Mean*
	Dwarf Champion	Break O'Day	Pritchard	
	Untreated			
1.0	2.10	3.71	3.21	3.007
1.5	2.24	3.65	3.13	3.007
2.0	2.23	3.52	3.07	2.940
3.0	2.30	3.56	3.22	3.027
4.0	2.37	3.42	3.32	3.037
	Staked not Pruned			
1.0	2.26	3.80	3.49	3.183
1.5	2.24	4.30	3.40	3.313
2.0	2.24	4.00	3.42	3.220
3.0	2.50	4.20	3.64	3.447
4.0	2.51	3.91	4.10	3.507
	Staked and Pruned to Three Stems			
1.0	2.54	4.15	3.60	3.430
1.5	2.70	4.63	3.71	3.680
2.0	2.70	4.87	4.10	3.890
3.0	2.90	5.37	4.00	4.090
4.0	3.04	4.80	3.82	3.887
Mean†	2.458	4.126	3.549	

*Significant difference = 0.013.
†Significant difference = 0.039.

based on all fruits harvested and expressed in ounces. Highly significant F values were found for varieties and for treatments. The interaction of spacings x treatments was significant also. Staking alone and staking plus pruning show a tendency to increase fruit size with staking plus pruning being slightly more effective in general and definitely more so for the Break O' Day variety. The increase per fruit for this variety was more than one ounce and approximately 33 per cent over the fruit size of the untreated plants. It may be expected that the extreme differences in spacing would affect fruit size, and there appears a tendency to smaller fruits in the closer spacings but the tendency was not uniform and definite enough to show an F value indicating significance. The value obtained is 2.92 which approaches the 5 per cent value of 3.01. It seems quite possible that a more extensive test would have shown a smaller fruit size in the closer planting, but it is of interest that the difference may be so slight.

Considering the results in relation to growing the crop there are suggestions of some interest. With emphasis on early production it seems desirable to prune and stake the Break O' Day type to increase early yields. However, this treatment may reduce the early yield of the self-pruning or determinate types as represented by the Pritchard variety. Staking without pruning may increase the early production of

the latter. Staking and especially staking plus pruning seemed to generally increase fruit size.

Spacing as close as 1 x 4 feet increased yields uniformly for all varieties and treatments under test. Fruit size may be reduced but the reduction in this test was not large enough to be considered statistically significant.

A Foliar Diagnosis Study of Greenhouse Tomato Plants Showing Symptoms of Streak Disease[1]

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INTRODUCTION — NUTRITION AND SUSCEPTIBILITY

THE virus nature of the disease commonly described as streak of tomatoes is well established. It can be caused by different viruses and is, in many cases, produced by a mixture of viruses (1, 3, 4).

As one means of control, the determination of the particular virus concerned has been suggested; but this method of approach may be ineffective without a knowledge of the susceptibility of the host in relation to its nutrition. This gap can be filled by the application of the method of foliar diagnosis (6, 8, 10, 11), a simple and highly sensitive procedure for comparing the mode of nutrition of infected plants with that of healthy ones grown under similar conditions.

Since resistance to infection is probably associated with a particular gene, which in turn can be influenced by a number of factors directly or indirectly affecting nutrition, it is possible that in the future, with a greater knowledge of the relation of nutrition to genetic structure, a better understanding of resistance to disease and nutrition will be had. In the meantime, the method of foliar diagnosis can be of service in determining the chemical condition with respect to the mineral nutrition in the synthetic laboratory of the plant — the leaf — without making any attempt to indicate whether the "chemism" associated with the outward manifestations is cause or effect.

The purpose of this investigation is to examine the nutrition, with respect to the dominant mineral elements, of low-yielding tomato plants exhibiting characteristic symptoms of streak disease with those of high-yielding, healthy plants grown under similar greenhouse conditions except with respect to fertilizer treatment.

MATERIALS AND METHODS

Description of Beds:—The plots, 5¾ feet wide by 8 feet long, contained 12 plants in three rows of four plants lengthwise across the plot (2). The surface soil consisted of a compost of clay loam and manure of depth 14 inches, and the subsoil of a clay loam. The beds were divided into 20 plots. The plants — a Pennsylvania certified strain of Marglobe — were grown in 4-inch clay pots from seeds sown on January 15th and were transplanted to the beds on March 9th and trained to a single stem to a height of 7 to 7½ feet.

Fertilizer Treatment:—Fertilizer treatments consisted of single elements and of binary and tertiary combinations of nitrogen, phosphoric acid, and potash supplied in nitrate of soda, superphosphate, and muriate of potash, respectively.

Of the two plots with which this report is concerned, one, No. 8L, received rotted horse manure together with the tertiary combination

[1]Authorized for publication on March 28, 1940, as paper No. 965 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

of mineral fertilizers given below, and the other plot, No. 12L, nitrogen only without any manure.

In Table I, these fertilizer treatments are indicated by the symbols (RN)PK + manure and N, respectively; the letter "R" indicates that unit amounts of nitrogen were supplied biweekly, commencing March 8th.

The quantities supplied were as follows: To plot No. 8L, 110 pounds of manure together with 4.60 pounds nitrate of soda, 1.38 pounds superphosphate, and 0.19 pound muriate of potash. This quantity of manure contained 422.1 grams of nitrogen (N), 274.9 grams of phosphoric acid (P_2O_5), and 345.8 grams of potash (K_2O); and the fertilizer, (RN)PK, 336.8 grams N, 125.2 grams P_2O_5, and 43.1 grams K_2O. To the other plot, No. 12L, was applied on March 8th 0.58 pound of sodium nitrate only; this amount was equivalent to 42.1 grams of N.

The per acre quantities applied to plot No. 8L would be approximately 4,000 pounds of nitrate of soda, 1,250 pounds of superphosphate (20 per cent P_2O_5), and 350 pounds of muriate of potash, together with 50 tons of manure; to 12L, approximately 500 pounds of nitrate of soda only.

Culture Methods:—Pollination was carried out by means of a watch glass applied to the stigmas of well opened flowers at midday on clear days. Copper-lime dust was applied at 10-day intervals until the plants were about 4 feet high. Water was supplied when required from a hose by allowing the water to run on each plot for the same length of time.

The plants which received dressings of manure together with the tertiary fertilizer developed normally and remained healthy up to the time of their removal from the beds on July 18th. On the other hand, by June 1st it was observed that a large number of the plants on the plot which received the dressings of sodium nitrate only (plot No. 12L) showed symptoms of disease. The disease appeared also on certain other plots which received commercial fertilizer only, though later in the season and with lesser severity.

Symptoms of Infection:—The characteristic symptoms of the streak disease which were exhibited by the plants of plot 12L were light yellow, elongated, irregular areas on the young leaflets at the tip of the vine, which later turned brown and became dead. Elongated brown lesions appeared longitudinally also on the petioles and stems, as well as on the larger veins of the leaflets, and the portions of the stems and petioles which were affected became brittle. A few brown, somewhat elongated, irregular spots were observed on fruits also. During the season, new terminal growth appeared healthy at times, and later exhibited symptoms of disease; this characteristic served to differentiate the disease from mineral deficiency, from which *recovery does not occur in new growth without additions of the deficient nutrient.*

Sampling Leaves:—By June 6th all leaves below the 14th from the base on the plot which received nitrate of soda only had died. On June 10th the 16th leaf from the base and also the 24th leaf were removed from all plants on the plot No. 8L; and from plot No. 12L

the 16th and also the 24th leaf were removed from plants showing no visible symptoms of disease (II); plants showing slight symptoms (III), and from plants severely diseased (IV). It was very likely that all plants were exposed to infection, because, in pruning, no precautions were observed to prevent transfer of juices from one plant to another.

Method of Analysis:—The leaves were thoroughly brushed and afterwards dried at 100 degrees C, ground to a fine powder in a Wiley mill, and analyzed by methods (6) which give the total amount of the respective elements, irrespective of the form in which they are present.

Results and Discussion

In Table I are given (a) the percentages of nitrogen, phosphoric acid, potash, lime, and magnesia present in the dried foliage together with (b) their milligram equivalent values and (c) in the case of the three plastic (labile) elements, nitrogen, phosphoric acid, and potash, also the composition of the *NPK-unit* (6).

Although the healthy plants received calcium in the superphosphate, whereas the diseased plants received none, nevertheless the CaO content of the 16th leaves of the apparently healthy plants of the latter is higher than that of those of the healthy plants of plot No. 8L. There is, consequently, no evidence of deficiency of CaO.

The CaO content of the 16th and 24th leaves of the resistant plants (plot No. 8L) is identical and there is only slight difference in their MgO contents.

On the other hand, both CaO and MgO in leaves of all types from the susceptible plants (plot No. 12L) follow the normal course of progressive increase with maturity of the leaf (6, 8, 9).

Both the CaO and also the MgO content decrease progressively from the apparently healthy leaves of plot No. 12L to the slightly diseased plants and thence to the severely diseased ones. The values, therefore, of the slightly diseased leaves with respect to CaO and MgO are intermediate between those of the apparently healthy and the severely diseased.

A reduction in CaO and MgO, then, is concomitant with increasing severity of the disease.

The MgO content of all types of leaves from the diseased plot is much higher than that of the healthy plants of plot No. 8L. The diseased plants then tend to supplement a lack of potash by an increase in another base, MgO (7).

But no actual deficiency of these bases in the diseased plants exists, for these combined bases are higher in the leaves of apparently healthy and slightly diseased plants of plot 12L than in those of the healthy plants and very little difference occurs even in those of the severely diseased plants.

We may, therefore, confine our examination to the plastic elements, nitrogen, phosphoric acid, and potash, for in the absence of any deficiency of bases CaO and MgO the mode of nutrition of the plant is determined in a large measure by the amounts and the physiological relations of these labile elements (6).

TABLE I—PERCENTAGES OF THE DOMINANT NUTRIENTS N, P_2O_5, K_2O, CaO AND MgO IN THE DRIED FOLIAGE, TOGETHER WITH INTENSITY OF NUTRITION, MILLIGRAM EQUIVALENTS, AND COMPOSITION OF THE NPK-UNITS OF HEALTHY TOMATO PLANTS COMPARED WITH THOSE OF PLANTS EXHIBITING STREAK DISEASE SYMPTOMS OF DIFFERENT DEGREE

Condition	Leaf No.	Mineral Content of Dried Foliage						Milligram Equivalents				Composition of the NPK-Unit		
		CaO (Per cent)	MgO (Per cent)	N (M_x) (Per cent)	P_2O_5 (M_y) (Per cent)	K_2O (M_z) (Per cent)	$N+P_2O_5+K_2O$ $(M_x)+(M_y)+(M_z)$ (s) (Per cent)	N (E_x)	P_2O_5 (E_y)	K_2O (E_z)	$E_x+E_y+E_z$ (S)	X $\left(100\frac{E_x}{S}\right)$	Y $\left(100\frac{E_y}{S}\right)$	Z $\left(100\frac{E_z}{S}\right)$
(RN) PK Plus Manure Plot No. 8L														
I All healthy	16	7.600	1.931	3.580	1.640	2.680	7.900	255.612	69.372	57.084	382.068	66.90	18.16	14.94
	24	7.600	1.925	3.900	1.480	3.643	9.023	278.460	62.604	77.596	418.600	66.51	14.95	18.54
	Mean	7.600	1.928	3.740	1.560	3.161	8.461	267.036	65.988	67.340	400.364	66.70	16.55	16.75
N (No Manure) Plot No. 12L														
II No visible symptoms	16	8.210	3.415	2.980	1.133	0.749	4.862	212.772	47.930	15.954	276.656	77.91	17.32	5.77
	24	5.710	3.385	4.440	1.133	1.518	6.991	317.016	47.930	32.333	397.279	79.80	12.06	8.14
	Mean	6.960	3.400	3.710	1.133	1.133	5.976	264.894	47.930	24.143	336.967	78.35	14.69	6.96
III Intermediate	16	6.813	3.050	2.860	1.106	0.465	4.431	204.204	46.784	9.904	260.892	78.28	17.93	3.78
	24	4.573	2.980	3.400	1.013	0.658	5.071	242.760	42.850	14.015	299.625	81.02	14.30	4.68
	Mean	5.693	3.015	3.130	1.059	0.561	4.751	223.482	44.817	11.959	280.258	79.65	16.12	4.23
IV Diseased	16	6.580	2.655	2.920	2.033	0.697	5.650	208.488	85.996	14.846	309.330	67.40	27.80	4.80
	24	4.588	2.000	4.080	1.655	0.699	6.434	291.312	70.006	14.889	376.207	77.43	18.61	3.96
	Mean	5.584	2.327	3.500	1.844	0.698	6.042	249.900	77.951	14.867	342.768	72.42	23.20	4.38

It should be mentioned here that in this soil (Hagerstown series) no evidence of a deficiency of the "oligoelements" or trace elements has been found; nor, in the composted soil of the greenhouse, is it likely that a deficiency of any of the plastic elements existed, to such an extent as to cause necrosis of young leaves or stems (2).

Action of a Fertilizer on the Mode of Nutrition

The addition of a fertilizer can affect the mode of nutrition of a plant by its effect either on the intensity of nutrition or on the quality of nutrition, that is, on the physiological relationships (ratios) between $N-P_2O_5-K_2O$ or in both values simultaneously (6, 10, 11).

The *quantity* factor — the intensity of nutrition — is expressed by the sum of the elements ("entities") $(N + P_2O_5 + K_2O)$ in the dried foliage at the moment of sampling and the *quality* factor by a consideration of the equilibrium between $N-P_2O_5-K_2O$ also at the moment of sampling. Since the latter magnitudes involve consideration of the reaction taking place in the leaf, they must be expressed in milligram equivalent values. These are shown in columns 9, 10, and 11 of Table I.

In order to determine these physiological relationships on a comparable basis, these milligram equivalent values are converted into a magnitude designated the NPK-unit. This unit is expressed in proportions of the milligram equivalent values by finding the sum of the milligram equivalent values for nitrogen, phosphoric acid, and potash, respectively, and then determining the proportion which each bears to this total. The values so obtained are multiplied by 100 to avoid fractional values. The NPK-unit then represents the equilibrium between $N-P_2O_5-K_2O$ in the selected leaves at the moment of sampling. These are the values shown in the last three columns of Table I.

The values of the *NPK-units* of the 16th and 24th leaves, respectively, taken on June 10th from plants growing on plot No. 8L, which received complete fertilizer together with dressings of manure and on which all plants were healthy, and also the values for the three types of leaves of the plants from plot No. 12L which received nitrogen only without manure are plotted in trilinear coordinates in Figs. 1 and 2.

The Intensities of Nutrition

The intensities of nutrition with respect to nitrogen, phosphoric acid, and potash of the 24th leaves of plants from each set show relationships of values to each other which are similar to those of the 16th leaves. The intensities of all three types of leaves from the diseased plot No. 12L are lower than those of the resistant plants of plot No. 8L.

As one passes from the leaves of apparently healthy plants of plot No. 12L to those of slightly diseased and thence to those of severely diseased plants, however, the values of the leaves of slightly diseased plants are not intermediate between those of the apparently healthy and the severely diseased plants from the same plot as we should expect, but are lower. An explanation of such anomalous behavior is that the condition is a reflection of the reaction of the plant at a late stage of the disease to overcome it, and is best shown by means of the physiological ratios between the plastic elements.

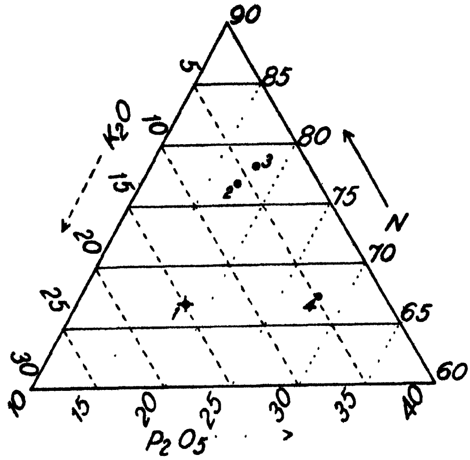

FIG. 1. Positions of the *NPK-units* of the 16th leaf from the base of healthy plants (plot No. 8L) in relation to those of diseased plants (plot No. 12L). 1–8L, (RN)PK plus manure, healthy; 2–12L, N, no visible sign of injury; 3–12L, N, slightly diseased; 4–12L, N, severely infected.

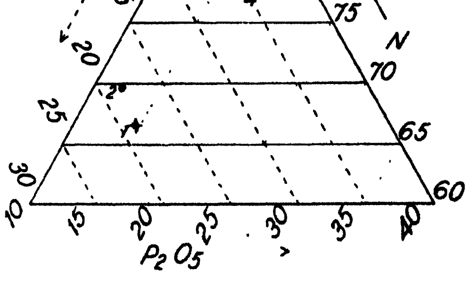

FIG. 2. Positions of the *NPK-units* of the 24th leaf from the base of healthy plants (plot No. 8L) in relation to those of diseased plants (plot No. 12L). 1–8L, (RN)PK plus manure, healthy; 2–12L, N, no visible sign of injury; 3–12L, N, slightly diseased; 4–12L, N, severely diseased.

THE PHYSIOLOGICAL RELATIONS BETWEEN THE PLASTIC ELEMENTS

The discussion of the relationships is rendered simpler by considering the values of the means of the 16th and 24th leaves. This procedure is valid because the former may, from the point of view of physiology, be regarded as the latter in a more advanced state of development; and in conformity with this, as inspection of Figs. 1 and 2 show, the positions of the 16th and 24th leaves relative to one another are similar.

The positions of the NPK-units of the several types of leaves of plants growing on the plot receiving nitrogen only are far removed from those of the leaves of the plants growing on plot No. 8L which received a complete fertilizer with manure. Furthermore, the position relative to that of these healthy plants (plot No. 8L) indicates the nature of its disequilibrium between N–P_2O_5–K_2O.

The leaves of plants which showed no visible symptoms of infection, of slightly diseased plants, and those of severely diseased plants of plot No. 12L, and indicated by numerals 2, 3, and 4, respectively, in the figures, are characterized by a displacement relative to that of the healthy plants of plot No. 8L towards

the summit apex and away from the left base apex, indicating a higher relative proportion of nitrogen and lower proportion of potash in the NPK-unit.

The value for potash, moreover, in those leaves of No. 12L which at the time of sampling (June 10) showed no visible indications of infection, is higher than it is in the leaves of diseased plants. But relatively little difference exists in the position with respect to the right base apex (P_2O_5 = 100 per cent) between those leaves of No. 12L which showed no visible signs of infection and also those of the slightly diseased ones from those of the healthy plants of No. 8L, indicating that the values for phosphoric acid in the NPK-unit have not been affected. The position of the leaves of severely diseased plants with respect to those of the healthy plants, however, is displaced further towards the right base apex (P_2O_5 = 100 per cent) than any, indicating the highest value for P_2O_5 in the NPK-unit.

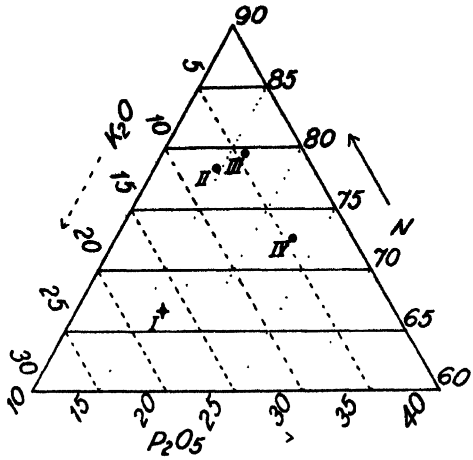

FIG. 3. Positions of the mean values of the NPK-units of the 16th and 24th leaves, respectively, from (I) healthy plants (plot No. 8L) in relation to those of (II) apparently healthy, (III) slightly diseased, and (IV) severely diseased plants of plot No. 12L.

The actual distances of the coordinates marked II, III, and IV, respectively, on the triangle (Fig. 3) from that of the coordinate marked I do not differ much. In other words, *quantitatively* the degree of disequilibrium is similar in all types of leaves of No. 12L, whereas, as shown above, qualitatively differences do exist.

TABLE II—THE MAGNITUDE OF THE PHYSIOLOGICAL RATIOS BETWEEN ANY TWO OF THE VARIOUS ENTITIES IN THE LEAVES FROM DIFFERENT TYPES OF PLANTS

Plot	Leaf No.	Condition	N/P_2O_5	P_2O_5/K_2O	N/K_2O
8L (RN) PK plus manure	16 24 Mean	All healthy	3.79 4.45 4.12	1.21 0.80 1.00	4.48 3.58 4.03
12L (N only)	16 24 Mean	Apparently healthy	4.44 6.61 5.52	3.00 1.48 2.24	13.33 9.81 11.57
12L (N only)	16 24 Mean	Intermediate	4.37 5.66 5.01	4.74 3.19 3.96	20.70 17.33 19.01
12L (N only)	16 24 Mean	Severely diseased	2.43 4.16 3.29	5.78 4.69 5.23	14.04 19.80 16.92

Comparison of the Values of Certain Magnitudes Showing the Physiological Relationships Between Healthy and Susceptible Plants

These qualitative differences can be exhibited by a consideration of the ratios between two of the entities, N/P_2O_5, $P_2O_5/K\ O$, and N/K_2O in the NPK-units of the 16th and 24th leaves, respectively, and shown in Table II.

No relationship exists between the value of the ratio N/P_2O_5 in the leaves of the vigorous, healthy plants on plot No. 8L and that in those of the three types of plants on plot No. 12L having diseased plants. But the differences in the P_2O_5/K_2O ratios and also in the N/K_2O ratios are striking. These ratios are very much greater in all types of leaves on plot 12L than on plot No. 8L, and, moreover, the ratio P_2O_5/K_2O is progressively greater with the severity of the symptoms.

Control Measures

With respect to the method of control suggested by the facts, it is logical to assert that any modification of the mode of nutrition that would cause the coordinate points, marked 2, 3, and 4 on the diagram, to approach or coincide with the coordinate point of the resistant plants, marked 1 in the figures, would also cause the growth characteristics of these plants to approach or be similar to those of the healthy and resistant plants.

The first step would obviously be to make an application of potash in some form. It is, therefore, pertinent to inquire how early in the growth cycle remedial measures would be possible. As an approach to this problem, an examination of the data in Table III, which shows the mean values for the intensities and *NPK-units* of the *5th leaf* taken from the plants on plots, 8L and 12L on April 5, April 29, and May 27 before any visible manifestations were indicated, is instructive.

The differences in the values of the intensities and of the physiological ratios of the plastic elements between the healthy plants (plot No. 8L) and of the diseased plants (plot No. 12L) are qualitatively similar to the values obtained on June 10th. Thus, there is a reduction in the intensity of the diseased plants, an increase in the nitrogen of the NPK-unit, a marked increase in the phosphoric acid, and a sharp decrease in the potash. The ratios of the individual elements to one another consequently show the same relationships as those of Table II.

TABLE III—Mean Values of the Intensities of Nutrition and Also of the Composition of the NPK-Units, Together with Ratios of Each Element to the Other (Data Are for the 5th Leaf from the Base Taken April 5, April 29, and May 27, 1938)

Plot	Treatment	Mean Intensity	Mean NPK-unit			Ratios, One Element to Another		
						N/P_2O_5	P_2O_5/K_2O	N/K_2O
8L	(RN) PK plus manure	7.83	71.22	13.89	14.89	5.13	0.93	4.77
12L	N (no manure)	5.89	72.71	21.02	6.27	3.46	3.56	11.60

These results suggest that the essential information might have been given at the first date of sampling on April 5. This is, in fact, the case as the values on this date given in Table IV testify.

TABLE IV—THE INTENSITIES OF NUTRITION AND THE NPK-UNITS OF THE 5TH LEAF SAMPLED APRIL 5

Plot	Treatment	Intensity	NPK-unit			N/P_2O_5	P_2O_5/K_2O	N/K_2O
8L	(RN) PK plus manure	8.94	73.85	11.45	14.70	5.11	0.98	5.02
12L	N (no manure)	7.05	79.59	12.59	7.82	6.32	1.61	10.17

SUMMARY

In a greenhouse experiment with differentially fertilized tomatoes with and without manure, the plants on one plot treated with nitrogen only without manure exhibited symptoms of having become infected with the virus causing streak disease, 10 weeks after planting.

The method of foliar diagnosis (6) was applied to determine the nature of the disequilibrium between the labile (plastic) elements in the leaves of diseased plants by means of a comparison of the intensities of nutrition and of the physiological relations with respect to nitrogen, phosphoric acid, and potash in the 16th and 24th leaves from the base, respectively, of diseased plants with those of morphologically homologous leaves of healthy, vigorous and probably resistant plants.

The physiological relations (ratios) are indicated by a magnitude designated the NPK-unit which represents the equilibrium between $N-P_2O_5-K_2O$ in the selected leaves at the moment of sampling. The derivation and method of calculating the NPK-unit are described.

The results indicate that the symptoms of infection of the virus causing streak were associated with a lower intensity of nutrition and a disequilibrium with respect to nitrogen, phosphoric acid, and potash manifested predominantly by much higher values for nitrogen, and much lower values for potash in the NPK-unit of diseased compared with healthy plants.

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A Preliminary Report on Two Plants Versus One Tomato Plant per Stake[1]

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THE spacing of trained and untrained tomato plants has long been a topic of practical concern. This interest is justified since commercial tomato growers are using a wide range of planting distances. It is recognized that the fertility of the soil, the variety, and the seasonal variations in climatic environment are important factors in determining the proper spacing of tomato plants. Nevertheless, it is interesting to note the similarity in yield trends of both field tomatoes, found by research workers in widely separated districts of the United States [Sayre (4), Rosa (3), Huelson (2), Smith and Associates (5), Thompson (6), and Woods (7)], and greenhouse tomatoes [Zimmerley (8), and Hoffman (1)]. No attempt has been made to review all the literature on the subject, but a few citations are given to show the variation in recommendations and the general agreement that closer planting tends to increase yields.

Since nearly all the profit from the market crop of tomatoes in West Virginia is acquired in the first two weeks of the harvest periods, the possibility of closer spacing as a means of increasing early production was considered particularly important.

The usual planting distance for staked tomatoes in West Virginia is 4 feet between the rows and 2 feet in the row. If a closer planting distance is to be of benefit to the grower, more must be produced to compensate for additional plants, labor, stakes, and twine. Under the conditions of this experiment, the additional cost of stakes and twine was eliminated by setting two plants per stake. Although twice the number of plants are required, it is estimated that the labor for setting, pruning, and training was only 50 per cent higher than for plants set 4 by 2 feet. With the exception of the plants, all other items of cost were pratically the same.

Plants of the Break O'Day variety were used. They were grown by planting the seeds in flats and transplanting the seedlings, when large enough, to ground beds in the greenhouse. Here they were allowed to grow until early May, when they were set in the field.

The field trial was conducted in 1940 at the Lakin Experiment Farm of West Virginia University on a Wheeling sandy loam soil of moderate fertility. It consisted of 20 rows 74 feet long spaced 4 feet apart. The stakes were set 2 feet apart in the row and in the alternate rows two plants were set per stake. This resulted in systematic distribution of the replications. Guard rows were set on each side of the planting. An application of 1,500 pounds per acre of a 5–10–5 mixture of commercial fertilizer was broadcast uniformly over the area before the plants were set. An average growing season for that locality followed.

Yield records were taken of the number and the weight of the fruit

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of both the marketable and the total yields from each row. The fruits were considered marketable if they weighed over 3 ounces and were of desirable market quality. The pickings were made at 2- to 4-day intervals, at which time all fruits, regardless of size, were gathered if sufficiently colored to satisfy market demand.

From the data listed in Table I it is evident that all yield measurements favor the close planting very significantly. It also shows indirectly that the individual fruits produced from the rows containing the single plant per stake were slightly heavier (0.012 pound) than the fruits from the double plants, but not enough to compensate for the additional number of fruits produced by the pair of plants.

Although there were many more tomatoes produced in the rows having two plants per stake, the percentage of marketable fruit from the two treatments was practically the same.

Eighty-four per cent of the early fruits from the single plants was marketable, while 83 per cent was marketable from the double plants. In considering the total number of fruits for the season, 71 per cent produced on the single plants were marketable while 72 per cent were marketable from the double plants.

When the yields from Table I are calculated in tons per acre, there is a striking difference in favor of the double plants. The yield of early marketable fruit is 8.84 tons from the double and 6.48 tons from the single plants. The difference in total yield is even greater—15.58 and 10.68 tons respectively. Substantial net profits were obtained by setting two plants per stake.

The arrangement of the plots in this experiment was such that the double plants may have had an advantage in the competition for light, water, and nutrients. The results, however, are so definite that it is

TABLE I—COMPARISON OF MEAN ROW YIELD FROM SINGLE AND DOUBLE PLANTS PER STAKE

Grade	Determination	Treatment	Yield	Difference	Odds*
	Early Yields (July 12 to July 25 Inclusive)				
Marketable	Number of fruits	Double Single	302.0 209.8	92.2	Highly significant
	Yield (pounds)	Double Single	120.2 88.1	32.1	Highly significant
Total	Number of fruits	Double Single	363.6 249.5	114.1	Highly significant
	Yield (pounds)	Double Single	140.3 101.1	39.2	Highly significant
	Yield for Entire Season				
Marketable	Number of fruits	Double Single	551.0 360.7	190.3	Highly significant
	Yield (pounds)	Double Single	211.8 145.2	66.6	Highly significant
Total	Number of fruits	Double Single	767.7 505.0	262.7	Highly significant
	Yield (pounds)	Double Single	267.1 181.8	85.3	Highly significant

*Odds greater than 9999.0 to 1.

probable, in view of the work of Thompson (6), Sayre (4), Rosa (3), and others, that significant differences will persist, to a certain extent, under several different environments. During a drought, or a period of insufficient rainfall, the yield difference would probably be less. Yet, under irrigation or ideal climatic conditions the yield difference favoring the double plants may have been greater. In growing the Break O'Day, which is the standard early variety of this section, or other varieties which produce a minimum amount of foliage, the added protection afforded by the increased foliage of the double planting is probably of importance in the prevention of sunscald. This work will be repeated under comparable conditions.

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Productivity of F_1 Hybrids in the Squash, Cucurbita Maxima[1] [2]

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THE monoecious nature of plants of the Cucurbita genus favors cross-pollination and the species usually is considered to be naturally cross-pollinated tho self-fertilization may occur. Darwin (5) concluded that self-fertilization was often injurious and cross-fertilization beneficial in naturally cross-fertilized species. Investigations by other workers tend to confirm Darwin's conclusions and have led to the belief that self-fertilization in such species results in loss of vigor. However, results obtained by several workers (1, 2, 3) suggest that neither selfing within a variety or intercrossing inbred lines of a variety has a pronounced effect on vigor in *Cucurbita maxima*. Similar results have been obtained (6, 8) in the closely related species, *C. pepo*. However, some investigators (4, 7) have reported on *C. pepo* crosses which exhibited considerable heterosis. This paper reports the results of a study of total yield, yield of mature fruit, weight per fruit, number of fruits per plant, and maturity in 10 *C. maxima* crosses and the parents.

MATERIALS AND METHODS

Minnesota selection 31 was used in all but one of the crosses. The other parents were inbred lines of Minnesota selection 32 (a sister selection of Minnesota selection 31), Greengold, Banana, Arikara, Blue Hubbard, Kitchenette, Delicious, New Brighton Hubbard, Banquet, and Mammoth Chili. All bred true for their readily observable characters except Mammoth Chili which varied somewhat in color.

Plants were started in the greenhouse May 20th and transplanted to the field June 4th. In the field, the plants were spaced 9 by 9 feet in four randomized blocks, using five plants of each kind in each block. Variances obtained for total yield per plant, mature yield per plant, weight per mature fruit, number of fruits per plant, and maturity, as indicated by the number of days from sowing to the production of the first female flower, indicated significant differences between varieties in these characters.

EXPERIMENTAL RESULTS

A comparison of average total yield per plant, average mature yield per plant, average weight per fruit, average number of fruits per plant, and maturity of the F_1 generations and their parents for individual comparisons is presented in Table I.

As can be seen from the data in Table I, there was no significant difference between the F_1 and the parents in any of the characters

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TABLE I—Total Yield, Yield of Mature Fruit, Weight per Mature Fruit, Number of Fruits per Plant, and Maturity of F_1 Crosses and Their Parents

Variety or Hybrid	Yield Per Plant		Weight Per Mature Fruit (Lbs)	Fruits Per Plant (Number)	Days From Seeding to First Female Flower (Ave. Number)
	Total (Lbs)	Mature Fruit (Lbs)			
Greengold	31.8	26.1	2.7	12.6	56.5
Selection 31	31.6	26.5	3.0	11.5	54.7
Mean of parents	31.7	26.3	2.9	12.1	55.6
Mean of F_1s^+	32.1	26.6	3.1	11.5	57.1
Banana	36.2*	33.6	7.6	5.0**	62.9*
Selection 31	31.6*	26.5*	3.0**	11.5*	54.7*
Mean of parents	33.9**	30.1*	5.3**	8.3	58.8
Mean of F_1s^+	52.5	43.6	6.9	8.4	58.7
Banana	36.2*	33.6	7.6	5.0**	62.9**
Selection 32	35.5*	32.0	3.3**	11.3*	57.7
Mean of parents	35.9*	32.8	5.5**	8.2	60.3**
Mean of F_1s^+	53.6	43.5	7.4	8.3	56.1
Arikara	16.9**	13.1**	5.0**	3.7**	53.0
Selection 31	31.6**	26.5**	3.0**	11.5*	54.7
Mean of parents	24.3**	19.8**	4.0**	7.6	53.9
Mean of F_1s^+	55.0	49.9	7.1	8.7	52.4
Blue Hubbard	30.1**	26.7**	10.0**	3.6**	73.5**
Selection 31	31.6**	26.5**	3.0**	11.5**	54.7**
Mean of parents	30.9**	26.6**	6.5	7.6	64.1
Single F_1	59.5	59.0	7.3	8.0	61.7
Delicious	20.6**	16.6**	9.3**	2.7**	57.4
Selection 31	31.6**	26.5**	3.0**	11.5**	54.7
Mean of parents	26.1**	21.6**	6.2**	7.1	56.1
Mean of F_1s^+	56.2	52.9	7.6	7.5	55.4
New Brighton Hubbard	33.9**	22.4**	24.0**	2.0**	77.9**
Selection 31	31.6**	26.5**	3.0**	11.5**	54.7**
Mean of parents	32.8**	24.5**	13.5**	6.8	66.3**
Mean of F_1s^+	58.9	54.3	10.8	6.0	61.0
Banquet	28.7*	24.3*	7.2*	4.4**	66.3**
Selection 31	31.6*	26.5*	3.0**	11.5*	54.7*
Mean of parents	30.5**	25.4**	5.1*	8.0	60.5*
Mean of F_1s^+	49.3	44.1	6.1	8.7	58.0
Kitchenette	52.9	45.9	5.3	11.1	66.1**
Selection 31	31.6*	26.5*	3.0**	11.5	54.7*
Mean of parents	42.3	36.2*	4.2*	11.3	60.4*
Mean of F_1s^+	52.1	48.2	5.3	10.3	57.8
Mammoth Chili	89.3	77.7	18.0**	5.9*	62.9*
Selection 31	31.6**	26.5**	3.0**	11.5*	54.7**
Mean of parents	60.5**	52.1**	10.5	8.7	58.8
Mean of F_1s^+	88.3	80.6	11.1	8.4	59.4

*Difference from the F_1 significant to the 5 per cent point.
**Difference from the F_1 significant to the 1 per cent point.
+Mean of reciprocal crosses.

studied in the cross between Greengold and selection 31. Greengold and selection 31 were derived from sister inbred lines and differ little from each other. Greengold produced a higher yield in previous tests than did selection 31 and it seemed desirable to include this cross in the test to determine the reaction obtained when two closely related lines were crossed.

The Banana was crossed with selections 31 and 32 which varied little from each other. Selection 32 produced a somewhat larger yield and was slightly later than selection 31. The data in Table I indicate that these crosses behaved in a similar manner.

In the Banana crosses and the crosses between selection 31 and Arikara, Blue Hubbard, Delicious, New Brighton Hubbard, and Banquet, the total yield per plant of the F_1 was significantly higher than that of the higher yielding parent. The F_1 also produced a larger yield of mature fruit than did the higher yielding parents. However, the increase, tho fairly large, was not significant in the Banana crosses.

In the crosses between selection 31 and Kitchenette and Mammoth Chili, no significant difference was obtained between the F_1 and the larger yielding parent in total yield. However, the F_1 produced a significantly larger yield than did the lower yielding parent in both crosses, a significantly larger yield than the mean of the parents in the Mammoth Chili cross, and a considerably larger yield than the mean of the parents in the Kitchenette cross. In both crosses, the F_1 produced a slightly higher yield of mature fruit per plant than did the larger yielding parent and a significantly higher yield than the mean of the parents.

It is interesting to note the behavior of characters whose combined effect may be responsible, in part, for the differences in yield. Among such characters are the average weight per fruit, average number of fruits per plant, and maturity as indicated by the number of days from seeding to the production of the first female flower.

From the data in Table I, it can be seen that the average weight per fruit of the F_1s exceeded that of the parent having the larger fruits only in the cross between Arikara and selection 31. In nine crosses, the average weight per fruit was significantly larger than that of the parent producing the smaller fruits and in seven crosses significantly larger than the mean of the parents. In eight crosses, the average number of fruits per plant in the F_1 is significantly larger than that of the parent producing the smaller number of fruits but in no case is it larger than that of the parent producing the larger number. It should be noted also that, in all cases where there is an appreciable difference in maturity between the parents, the F_1 is significantly earlier than the later parent. In no case, however, is it significantly earlier than the earlier parent and only in four crosses is it significantly earlier than the mean of the parents.

Considering all the data in Table I, it may be stated that hybrid vigor, as expressed in increased total yield, is shown by most of the crosses studied. Part of this increase possibly may be explained as a result of the combined effect of other characters studied. As has been noted, the average weight per fruit of the F_1 was significantly larger than that of the parent having the smaller fruits and the average number of fruits per plant of the F_1 was larger than the number produced by the parent having the smaller number. The F_1, while not usually earlier than the early parent, was earlier than the late parent and usually earlier than the mean of the parents tho not significantly so in all cases. While these characters in themselves do not exhibit hybrid vigor, their combined effect may account for the increased yield of the F_1 to an appreciable extent.

Since eight reciprocal crosses between selection 31 and standard varieties were used, it is interesting to compare the yields obtained

TABLE II—YIELDS OF EIGHT RECIPROCAL CROSSES WHEN SELECTION 31 WAS USED AS A MALE AND AS A FEMALE PARENT

Crosses	Number	Mean Yield Per Plant (Pounds)	Difference
Selection 31 × standard varieties..............	8	54.88	1.56
Standard varieties × selection 31	8	56.14	—
Difference necessary for significance		(5 per cent point)	6.19

when selection 31 was used as the male and as the female parent. Such a comparison is presented in Table II.

While the data in Table II indicate no significant difference between the groups of reciprocal crosses, there is some evidence that such reciprocal crosses, in some cases, may exhibit significant differences. Such differences may be due not to inherent differences in yielding ability but to the effect of different size seed coats in the parents which, in some cases, may restrict the growth of the F_1 embryo. Passmore (7) reports on such a case in reciprocal crosses of *Cucurbita pepo*. Her results show that hybrids from the larger embryos are markedly larger during early development but that plants from the small embryos tend to catch up with those from the large embryos during the later stages of development. A comparison of yields obtained from three sets of reciprocal crosses between large and small seeded parents is presented in Table III.

TABLE III—YIELD OF THREE RECIPROCAL CROSSES BETWEEN LARGE AND SMALL SEEDED PARENTS

Crosses	Number	Mean Yield Per Plant (Pounds)	Difference
Small × large seeded.	3	57.40	11.87
Large × small seeded.	3	69.27	—
Difference necessary for significance		(5 per cent point)	10.10

The data in Table III suggest that differences due to restriction of size of the embryo may be present even at the time of harvest. If such is the case and F_1 hybrids are used in practical production, it might be advisable to use the large rather than the small seeded parent as the female parent. However, the data are not sufficient to warrant a definite conclusion on this point as yet.

SUMMARY AND CONCLUSIONS

Ten F_1 generations of crosses between selections and varieties of *Cucurbita maxima* were grown in four randomized blocks together with the parents. Of these, seven F_1s produced a significantly higher total yield than that of the higher yielding parent and three did not differ significantly from the higher yielding parent. In a cross between closely related selections, the F_1 did not differ significantly from the parents in any respect. In general, F_1s produced from crosses between parents which differed considerably in their readily observable characters, were significantly more productive than the higher yielding

parent. The combined effect of weight per fruit, number of fruits per plant, and maturity appeared to influence the increase in yield; in general, the F_1 weight per fruit was greater than the mean of the parents, the number of fruits per F_1 plant was equal to or slightly exceeded the mean of the parents, and the F_1 hybrids were somewhat earlier than the mean of the parents.

A comparison of eight reciprocal crosses showed no difference in total yield in the F_1. However, a comparison of three reciprocal crosses between large and small seeded parents showed a significant increase in total yield in the F_1 when the larger seeded variety was used as the female parent. Such differences possibly are due not to inherent differences in yielding ability but to the restricting effect of the seedcoat of the smaller seeded parent on the F_1 embryo.

The question arises as to whether hybrid vigor produced in F_1s of *Cucurbita maxima* crosses can be utilized in practical production. Results obtained in these crosses suggest that the use of certain F_1 hybrids might be feasible in this region. Rather high increases in yield were obtained in some crosses. However, it should be remembered that the data herein presented are the results of only one year's investigations and the effect of hybridization might not be so pronounced in another season or locality. Moreover, little is known concerning the method or cost of producing F_1 seed. By using tested parents and developing a simple crossing technic, it should be possible to produce hybrid seed that would give increased yields at a price that would not be prohibitive.

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Studies on the Resistance of Eggplant Varieties to Phomopsis Blight[1] [2]

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PHOMOPSIS blight of eggplant has been one of the principal limiting factors of eggplant production in the State of Rhode Island. Most commercial eggplant varieties are very susceptible (1, 2), and at present the use of fungicides for control has proved inadequate. The purpose of these studies was to determine the comparative resistance of varieties and to learn something of the nature of the resistance factor.

COMPARATIVE RESISTANCE OF VARIETIES

About 300 collections of eggplant seeds, chiefly from tropical Asia and the Americas, were supplied by the Agronomy department of this station in cooperation with the Bureau of Plant Exploration and Introduction of the United States Department of Agriculture. Only 106 samples germinated sufficiently well to provide material for adequate testing.

In order to test this volume of material, the primary determination of relative susceptibility was made in the greenhouse on seedlings and selected varieties were checked in the field. Thus, for every plant tested in the field, at least 100 were subjected to inoculum of *Phomopsis vexans* in the greenhouse under favorable conditions for infection. In this way, variation in the incidence of the disease from year to year and the irregularity of occurrence of inoculum in different parts of the test plats with consequent escape of infection is minimized.

GREENHOUSE TRIALS

In testing the resistance of seedling plants to the disease in the greenhouse, a row of seed of each of seven or eight varieties was planted across a flat of soil. The seedlings were generally allowed to attain a height of 2½ to 3 inches before being inoculated. They were then inoculated by spraying with a suspension of spores, and the flats of seedlings were incubated in a moist chamber for 30 to 48 hours before being returned to the greenhouse bench. Although the first symptoms of infection were visible in 8 to 10 days, maximum development of infection occurred in 30 days, at which time an index number was recorded for the severity of infection. In comparing the resistance of the numerous eggplant varieties to the disease, the very susceptible variety Black Beauty was used as a standard. The relative susceptibility of the various collections on the basis of the amount of tissue killed is shown in Table I. The fact that most varieties are very susceptible is emphasized, since almost half of the lots of seed gave rise to plants whose foliage was more than 65 per cent killed following inoculation.

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[2]Taken in part from a thesis presented by the junior author in partial fulfillment of the requirements for a Master of Science degree at the Rhode Island State College.

TABLE I—RESPONSE OF 94 SAMPLES OF *Solanum melongena* TO INFECTION BY *Phomopsis vexans*

Disease Index	Foliage Injury (Per Cent)	Number of Samples in Each Degree of Resistance
0	0	2
1	0–1	6
2	1–20	17
3	20–65	26
4	65–100	43

Results of the greenhouse determinations also showed that 12 collections of Solanum, other than *Solanum melongena,* were immune to infection by *Phomopsis vexans* conidia.

FIELD TRIALS

A field trial of the more resistant varieties in comparison with commercial varieties was conducted in order to determine the resistance of the mature plants and fruits to *Phomopsis vexans*. Notes on the quality and the possible commercial value of the more resistant varieties were recorded. Forty-one varieties were set out in replicated rows of seven plants each. During warm, humid weather in July and again in August, 6 liters of a spore suspension of *P. vexans* were sprayed on the plants. Additional inoculum was provided by "spawning" the plats in late July with pure cultures of the fungus growing on autoclaved wheat grain, and on alfalfa, soybean, potato, and eggplant stems. Symptoms became evident about the first of September and were very severe on some varieties by the middle of September, but the final tabulation was made on October 10.

Results of the field trials were expressed by index numbers from 0 to 4 in order of increasing susceptibility, as for the seedlings in the greenhouse. The Black Beauty, Early Long Purple, New Hampshire hybrid, and Rhode Island hybrid (F_3–5–1) varieties had an index of 3 in the field compared with 4 in the greenhouse. Two collections of the "Gilo" variety from Brazil, which is a tall shrub with small red fruits, were immune to Phomopsis blight. No symptoms of the disease appeared on any of the species of Solanum planted other than on *Solanum melongena. S. indicum, S. pyracanthum, S. mammosum,* and seven unidentified types resembling nightshade, potato, tomato, and thistle in habit of growth appeared to be immune. In general, a given variety exhibited somewhat more resistance to infection in the field than in the greenhouse. Several varieties belonging to the "Pegan" and "Bengan" strains from India produced fruit of very good quality and type, and in addition were highly resistant to Phomopsis blight.

NATURE OF THE RESISTANCE FACTOR

It was hoped that a study of the ability of the pathogene to penetrate the leaf surfaces of eggplants of varying degrees of susceptibility to Phomopsis blight might throw some light on the nature of the "resistance factor". To accomplish this, several varieties of seedling plants about 2 inches tall were placed in moist washed quartz sand in finger

bowls and inoculated with a spore suspension. The finger bowls were covered with bell jars for a definite incubation period. The bell jars were then removed and a 1 per cent solution of celloidin atomized on the inoculated leaves to prevent washing off of the spores during clearing and staining processes. The chlorophyl was removed, after the celloidin film dried, by immersion of the leaf for 8 to 10 hours in a solution composed of 50 per cent glacial acetic acid, 37.5 per cent absolute alcohol, and 12.5 per cent chloroform. The material was stained with 0.5 per cent acid fuchsin in lactophenol according to the method of Davis in Riker and Riker (3). In order to avoid staining the leaf tissue as well as the spores, each drop of acid fuchsin-lactophenol was diluted with 4 or 5 drops of clear lactophenol as required.

The germ tubes of the spores were found to enter the leaves of both susceptible and resistant varieties by direct penetration of the cell wall of upper and lower epidermis alike. Although many spores were found to have germinated near open stomata, in no instance could it be demonstrated that the germ tube had entered the stomatal opening. Penetration apparently takes place by the dissolving of a hole in the wall of the epidermal cell through which the germ tube enters and seems to progress intracellularly through the tissues. Since resistance is apparently not structural or mechanical, its chemical or protoplasmic nature is indicated.

To determine the presence of a chemical substance which might confer resistance to *Phomopsis vexans,* autoclaved stems of resistant and susceptible eggplant varieties were inoculated and the subsequent mycelial growth compared. The fungus made almost equally good growth on all the stems tried. This indicates that the factor responsible for the resistance of the living plant is either thermolabile or acts only while the protoplasts are alive.

The pathogenesis of *Phomopsis vexans* seems to be confined in varying degrees to *Solanum melongena,* as previously shown. The saprogenesis of the fungus is not well known, especially since it has a bearing on control by crop rotation. Inoculation of sterile vegetative structures of a large number of field and garden crops with pure cultures of *P. vexans* and subsequent observation, showed that the fungus would grow on all the substrata tried, although sparsely in some instances. However, on cauliflower petioles, carrot roots, and beet roots, spore production was much greater than on eggplant tissues. Thus it seems that succeeding crops of eggplants may be inoculated by inoculum produced on plant debris other than eggplant residue in the soil. This would lessen the effectiveness of crop rotation as a control measure, as the fungus may survive for several years or indefinitely on the debris of subsequent crop plants.

To ascertain if any relationship exists between the degree of resistance of varieties to blight and the presence of growth-promoting or growth-inhibiting substances in the plant cells, the germination of spores was compared. Cell sap was extracted from freshly cut plants of six varieties by means of a hydraulic press and then centrifuged for 30 minutes. One volume of the cell extract was added to four volumes of a spore suspension containing approximately 50 spores per

low power microscopic field. Similarly, orange and tomato juices and distilled water were used as controls. Drops of the media were placed on glass slides in 6-inch petri dishes and incubated at 29 degrees C for 30 hours. The spores were found to germinate with greater vigor in the eggplant extract than in the controls. Although the spores generally germinated better in the cell extracts from susceptible varieties, the results were only indicative due to insufficient data.

In conclusion it appears that the growth of the Phomopsis blight pathogene is confined to living plants of *Solanum melongena,* and that it can grow vigorously on many kinds of dead plants. The relative resistance of varieties was comparable on the basis of greenhouse and field tests. The fungus penetrates equally well the leaf surfaces of all eggplant varieties tried, but since some did not develop symptoms of the disease, the resistance factor is considered to be protoplasmic or vital in nature. Varieties of eggplants resistant to Phomopsis do exist and await further development by the vegetable plant breeder and seedsman.

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Quality of Muskmelons as Related to Condition of Plants

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As IN many other sections, growers in Indiana are interested in improving the quality, as well as the yield, of their muskmelons, and buyers want, of course, to receive shipments containing a very high percentage of finely flavored fruits. In the course of studies on the effect of irrigation, spraying, dusting, and the use of fertilizers, borax and organic matter on quality at the Southwestern Indiana Horticultural Experimental Farm, it seemed desirable to keep records on the condition of plants from which sample melons were taken. It was hoped to determine how much certain characteristics of the plant, particularly leaf area per pound of fruit and freedom from diseases, affect muskmelon flavor and sweetness. Since greater ranges in plant condition sometimes existed among plants in various commercial fields in the vicinity of the experimental farm than on the plots, some data were taken on plants not in any test. For purposes of the present summary all records have been put together without regard to plot treatment.

Procedure

Data were taken on leaf area, per cent of leaves affected with diseases, weight and number of fruits on the vine, varietal type and on taste and refractive index of the juice of ripe fruits. Other characteristics of the fruit and its environment were recorded, but not used in arriving at the results given below. All this information was obtained at the time the ripe sample fruit was picked. Two hundred and forty-six complete sets of figures were obtained in 1939 and 492 complete sets in 1940. In 1939, especially, a great many incomplete sets were gotten and used for purposes such as correlating taste ratings with refractive indices.

In 1940, living leaf area was estimated by counting the leaves of each of three size groups and multiplying the numbers by an approximate average leaf area for each size group. Cardboard standards, patterns of leaves representing the limits of the size groups, were used in this counting and classification. In 1939 the same method was used except that, after the leaf areas of some plants were computed in the manner mentioned, the areas of others were estimated directly. Leaf area estimates were used together with careful estimates of total weight of fruit to get the leaf area per pound of fruit for each vine.

In 1939, counts were made on each plant of the number of leaves with at least one-fifth of their areas covered with disease lesions. A leaf was not counted as diseased, even though it was dying or dead from a systemic disease or another cause, if it had no apparent lesions. On the other hand, it was counted if it did have lesions even though it was dead and dried. The number of diseased leaves was then expressed as a percentage of the total number of leaves which the plant had ever had. This total number of leaves included both living leaves

and dead leaves, even ones of which only the petioles remained. In 1940 leaf disease was estimated in two ways, both of which seemed in some respects preferable to the 1939 method. In the first method the number of leaves which had at least one-fifth of their areas affected with disease or which were dead from leaf diseases or other causes, was estimated and again expressed as an approximate percentage of the total number of leaves which the plant had and had had, altogether. These plants were also rated according to the number of diseased, but partly living, leaves present; this latter figure was expressed in terms of the total number of living leaves. The second method had the advantage that the results obtained by it corresponded with the other data in that they represented a functional condition of the plant at time of sampling and, unlike those obtained by the first method, did not greatly reflect the condition of the plant in previous weeks.

For multiple correlation purposes, varieties of the Hales Best type were arbitrarily given the rating of 1.0 and those of the Globo de Oro type the rating 2.0.

Taste was judged by the following simple standards which were written out at the beginning of the 1939 season and were referred to regularly and frequently by the persons[1] making the tests:

An *excellent* melon (rating: 4.0) is a fruit richly flavored and very sweet, the kind of muskmelon that a consumer might remember favorably for a long time.

A *good* melon (rating: 3.0) is a melon which would still probably give a consumer considerable pleasure to eat when he was not really in need of food or water.

A *fair* melon (rating: 2.0) is a melon which a consumer would ordinary eat with very little complaint, even though he weren't hungry, but one which he wouldn't particularly enjoy and might not finish eating.

A *questionable* melon (rating: 1.0) is a melon which some consumers would eat and others would merely start to eat. This class includes nearly tasteless melons, ones lacking in both sweetness and aroma.

A *"no good"* melon (rating: 0.0) is one which has a definitely disagreeable flavor or one which has the cucumber taste of an immature fruit.

The types of melons described by these definitions are fairly distinct. The normal person notices much lesser differences when he makes direct comparisons between melons. Of course there are many borderline cases; to take care of these, melons were often rated, for example, good +(= 3.3), fair to good (= 2.5), and so forth. Nevertheless, it is understood that a taster cannot reliably assign melons to exactly the proper group or intermediate group and that occasionally appraisals of different persons may differ by a unit, or even more.

Tasting was always done and results recorded before refractometer readings were made.

[1]Most of the records were taken by two undergraduate students, Mr. J. E. Klinker in 1939, and Mr. Emil Wolf, in 1940. These two men were employed full-time to do this work in the summer under the supervision of the authors.

Refractive indices were determined with an Abbe apparatus in 1939. Juice was squeezed from small cork-borer plugs of flesh and was filtered. These plugs were always taken from the sides of the melons, about midway between the ends, because, as shown by Scott and MacGillivray (3), soluble solids content varies in a characteristic way from one part of a melon to another. Temperature was noted at each reading and to some extent controlled. Readings were in duplicate for each melon.

In 1940 Zeiss hand refractometers were used, after more than a hundred tests had shown that, when they were held at temperatures for which they were adjusted, they gave approximately the same readings as the regular Abbe refractometer. It was also found in preliminary work that unfiltered juice samples obtained by a method described orally by J. C. Hoffman, of the Ohio Agricultural Experiment Station, gave very nearly the same readings as filtered juice obtained by the 1939 method. There was no marked consistent difference between the results by the two methods. The simplified procedure was as follows: A melon was sliced in half longitudinally from top to bottom. After the seeds were removed, one half of the fruit was squeezed with one hand until a little juice collected in it. Then a few drops of this juice were poured directly from the fruit onto the prism having the polished surface. A reading was made at once.

When melons were on hand, ready for cutting, it was possible for two men to make and record indices of refraction at the rate of approximately one per minute, and to maintain that speed. The chief trouble experienced was that eventually some sand particles were squeezed between the prisms and marred their metal holders rather much and even the polished glass surface of one prism slightly. However, after each refractometer had been used for thousands of readings in regulatory work there was apparently no practical impairment of its accuracy.

The hand refractometers are calibrated to read in terms of percentage of sucrose, although, of course, other soluble solids affect the readings. All data obtained by their use are stated as soluble solids expressed as percentages of sucrose.

Results

In 1939 the simple correlation coefficient for the taste estimate and soluble solids was .62 ± .02 and in 1940, .53 ± .02. The indicated errors are probable errors. The corresponding regression equations are:

$$T = -1.699 + .466\ S$$

$$\text{and } T = +\ .218 + .261\ S,$$

where T is the taste index and S means soluble solids expresses as per cent sucrose.

For the sake of ease in interpretation, the information contained in these equations is also presented in Table I.

The coefficient of multiple linear correlation of soluble solids with leaf area per pound of fruit, varietal type and per cent of leaves diseased was .45 ± .02 in 1939. Only one varietal type was involved in 1940; so the correlation was for only two independent variables

TABLE I—DEPENDENCE OF TASTE ON SOLUBLE SOLIDS CONTENT AS INDICATED FROM THE SIMPLE REGRESSION EQUATIONS

Soluble Solids Expressed as Sucrose (Per Cent)	Taste Rating			
	1939		1940	
	Numerical Estimate (Units)	Approximate Verbal Equivalent of Numerical Rating	Numerical Estimate (Units)	Approximate Verbal Equivalent of Numerical Rating
5	.6	—	1.5	Questionable to fair
6	1.1	Questionable +	1.8	—
7	1.6	Questionable to fair	2.0	Fair
8	2.0	Fair	2.3	—
9	2.5	Fair to good	2.6	—
10	3.0	Good	2.8	Good−
11	3.4	Good to excellent	3.1	—
12	—	—	3.4	Good +
13	—	—	3.6	—
14	—	—	3.9	Excellent

on soluble solids. When per cent of leaves diseased was estimated by the first method used in 1940 the coefficient had a value of .47 ± .02, when leaf diseases were expressed according to the second method, the figure was only .35 ± .03. All of these values are statistically highly significant.

Regression equations calculated from the same data are as follows:

$$(1939)\quad S = 7.71 - .0245\,D_1 + .00223\,A - .506\,V$$
$$(1940a)\quad S = 11.39 - .0387\,D_2 + .00155\,A$$
$$(1940b)\quad S = 10.28 - .0296\,D_3 + .00222\,A$$

S represents soluble solids, expressed as per cent sucrose; D is per cent of leaves diseased; A, living leaf area in square inches per pound of fruit; and V, varietal type. D has been given different subscripts in the three equations because each equation is derived from leaf disease data estimated in a different way, as is explained under Procedure.

In Table II are given examples illustrating calculations which may be made from the multiple regression equations.

DISCUSSION AND CONCLUSIONS

It is evident that on the whole, refractive indices were useful indicators of muskmelon quality. They have not, however, been nearly

TABLE II—DEPENDENCE OF SOLUBLE SOLIDS CONTENT ON ABUNDANCE OF LEAF DISEASES AND ON LEAF AREA PER POUND OF FRUIT (HALES BEST VARIETAL TYPE)

Diseased Leaves (Per Cent)	Leaf Area per Pound of Fruit (Sq In)	Soluble Solids Expressed as Sucrose (Per Cent)		
		1939	1940a	1940b
60	100	6.0	9.2	8.7
60	400	6.6	9.7	9.4
60	1200	—	10.9	11.2
20	100	6.9	10.8	9.9
20	400	7.6	11.2	10.6
20	1200	—	12.5	12.4
0	100	7.4	11.5	10.5
0	400	8.1	12.0	11.2
0	1200	—	13.2	12.9

well enough correlated with taste to be used blindly as measures of edible quality. This lack of a high correlation is not entirely due to the unreliability of the sense of taste, although Currence and Larson (2), who had a number of persons check taste ratings, obtained much higher correlations than are here reported. When melons are obtained from various sources over a period of time, it has been obvious that other factors, especially the abundance of aromatic substances, can vary enough between melons of equal sweetness to produce occasionally edible qualities far out of line with those which would be expected from the refractive index of the juice. The variation in soluble solids content in melons of equal edible quality in Indiana was comparable to that reported by Chace, Church and Denny (1) for California melons. The difference between the simple regression coefficient of 1939 and that of 1940 is probably due to differences between the seasons but may be, to some extent, a measure of the taste preference differences of the persons who rated the melons.

The coefficients of A and D in the three multiple regression equations are nearly the same, surprisingly so in view of the fact that the meaning of D is somewhat different in each case and that disease was much more prevalent in 1939 than in 1940. As a matter of fact, it is probable that the method of estimating leaf disease in 1939 gave much the same results as the second method used in 1940. However, the standard errors of these coefficients are large enough to indicate that such close agreement could not be expected to occur often from calculations based on similar data.

It has been shown that leaf area, prevalence of leaf diseases and variety did have a very important effect on the soluble solids content of melon fruits. The multiple correlation coefficients are not large, but it must be considered that the ratings of disease and leaf area were in themselves necessarily inaccurate and that these ratings mainly indicated the condition of the plant when the fruit was ripe, whereas it might be expected that the condition of the plant in the previous week or two also affected fruit quality. One of the chief changes which sometimes occurred within a week and which was not reflected in the data taken was the change in weight of fruit on the vine. Often, perhaps, a mature fruit was removed just a day or two before the data were taken. Furthermore there are many other known and probable causes of variation in soluble solids which have not been taken into account. Chief among these is the variation in ripeness between melons even among those which were supposed to be picked when fully ripe.

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The Occurrence of a Spontaneous Triploid Celery

By THOMAS W. WHITAKER, *U. S. Horticultural Field Station, La Jolla, Calif.*

IN OUR celery cultures there appeared among plants of *Apium prostratum* Labill., a single plant, apparently a hybrid between this species and *A. graveolens* L. (celery). This plant produced flowers the first year, and has since assumed a perennial habit, suggesting that one of its parents may have been a variety of perennial celery.

FIG. 1. Photograph of *Apium prostratum,* A; *A. graveolens,* B; and the triploid hybrid, C; camera lucida sketches of meiosis in *A. prostratum,* D; *A. graveolens,* E; and the triploid hybrid F, (× 2000); G is a camera lucida sketch of mitosis in a root-tip cell of the triploid hybrid showing 33 chromosomes (× 2000).

TABLE I—A CMPARISON OF THE IMPORTANT CHARACTERS OF *Apium graveolens*, *A. prostratum*, AND THE TRIPLOID HYBRID

Contrasting Characters	*Apium prostratum*	Hybrid	*Apium graveolens*
Duration	Annual	Perennial	Biennial or perennial
Habit of growth	Prostrate	Semi-erect	Erect
Type of growth	Indeterminate	Indeterminate	Determinate
Length of petiole to first leaflet	5–7 Cm	10–12 Cm	15 Cm
Number of leaflets	2–5	2–3	2–3
Pigment on petioles	Present	Present	Absent
Size of seed	2×3 Mm	1×2 Mm	1×1½ Mm
Average number of flowers per unbel	19	16	15
Per cent of fertile pollen	75–80	5–10	90–95
Chromosome number	22 (2n)	33 (2n)	22 (2n)

From the seedling stage until it reached maturity this unusual plant gave every indication of being a hybrid between the two species. In several characteristics it was intermediate between them, namely, in habit of growth, number of leaflets, and so on. In type of growth (indeterminate), and in having pigment on the petioles it resembled *Apium prostratum*. In height, and in size of the floral parts it was similar to *A. graveolens* (see Fig. 1, A, B and C). The marked contrasting characters between the two species and the hybrid are listed in Table I.

The writer has examined several varieties of celery and all of them have 11 pairs of chromosomes (Fig. 1, E) as reported by Emsweller (2), Wanscher (4), and others. *Apium prostratum* also has 11 pairs of chromosomes (Fig. 1, D). Meiosis in the latter species shows a number of irregularities; lagging and the extrusion of one or two chromosomes into the cytoplasm have been observed. Pollen grain counts show that about 25 per cent of the microspores are sterile. This is another indication of considerable irregularity at meiosis in this species.

The presumed species hybrid is a triploid, and has 33 somatic chromosomes (Fig. 1, G). At meiosis pairing follows the *Drosera* scheme; there are regularly 11 bivalents and the same number of univalents (Fig. 1, F). Segregation of the chromosomes to the daughter nuclei seems to be at random; 17, 16, 15 and as few as 14 chromosomes have been counted at first anaphase. Only a small percentage of the pollen appears to be viable (5 to 10 per cent), and the plant is completely sterile.

There seems to be only one method by which this particular triploid could have originated, *i.e.*, through failure of reduction at meiosis of one parent, and the consequent fusion of a reduced (n) gamete with an unreduced (2n) gamete. Circumstantial evidence indicates that the triploid was produced by normal sperm of *Apium graveolens* fertilizing an unreduced egg cell of *A. prostratum*. The fact that the triploid came from seed harvested from plants of *A. prostratum* and that there are demonstrated irregularities of meiosis in this species is strong evidence in favor of the view that the genetic constitution of the hybrid may be represented by the formula PPG, where P = the *A. prostratum* genom, and G = the *A. graveolens* genom.

In Darlington's (1) discussion of triploid hybrids, it is found that

the triploid in question may be classified as the AAB type (crosses of diploids with unreduced diploids). This type of triploid with its peculiar pairing relationships at meiosis ($11^{II} + 11^{I}$) is of rather rare occurrence, and has been previously reported only by Müntzing (3) in *Galeopsis*.

Backcrosses of the triploid to both parents have thus far failed to produce viable seed. Doubling the chromosome complement by the use of the drug colchicine seems to be the most promising method of making use of the vigor and perennial habit of this plant.

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"Starter" Solutions in the Production of Cauliflower and Brussels Sprouts on Long Island[1]

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CONSIDERABLE interest has arisen recently with regard to the benefits from the use of nutrient solutions of varying compositions in place of the water usually employed in transplanting plants. Numerous formulas have been prepared and claim of increased survival of plants, and larger yields, have led to much interest among the growers. Cauliflower and Brussels sprouts on Long Island are normally transplanted by machine and the addition of mineral elements to the water would be relatively simple, so experiments were designed to obtain information on the advisability of such a practice.

The nine treatment solutions in Table I were arranged in four blocks and applied at planting time to cauliflower at the rate of about 1 pint per plant. A ton of a 4–8–6 analysis fertilizer was used and a single side-dressing of nitrate of soda was applied at the rate of 125 pounds per acre. From Table I it is apparent that none of the treatments employed exceeded water as a transplanting solution for cauliflower, in fact, the yields from the other treatments were numerically lower, though not significantly so, than the one using water.

The following year the 14 treatments resulting from combinations of seven growth promoting substances with minerals and no minerals were applied in three blocks for cauliflower and Brussels sprouts. Fertilizer of 4–8–7 analysis at rate of 2,000 pounds per acre was applied broadcast, and two side-dressings of nitrate of soda of 125 pounds per acre were applied. About a pint of solution was used for each plant and the data shown in Table II were taken.

TABLE I—Effect of 'Starter' Solutions of Varying Mineral Composition Upon the Weight and Rate of Growth

No.	Material Employed	Analysis	Lbs Per 100 Gallons	Mean Weight Per Plant (Grams) Sep 15	Mean Weight Per Plant (Grams) Oct 5	Growth Increment (Grams)	Harvest Yields (Crates Per Acre)
1	A. Superphosphate....	20 per cent P_2O_5	7.9	87.9	116.5	28.6	252
	B. Calnitro..........	20 per cent N	2.6				
	C. Potnit............	13.5 per cent N 46 per cent K_2O	2.0				
2	A+B only............	—	—	103.1	134.2	31.1	246
3	A+C only............	—	—	92.5	145.5	53.1	241
4	B+C only............	—	—	72.7	99.4	26.7	241
5	Control—water........	—	—	119.9	169.6	49.7	278
6	B+C+phosphoric acid..	H_3PO_4	3.3	107.5	138.7	31.2	204
7	Sodium nitrate........	16 per cent N	4.0	116.3	182.9	66.7	222
8	Phosphoric acid........	H_3PO_4	3.3	80.4	152.6	72.2	220
9	Potassium chloride.....	60 per cent K_2O	1.3	70.9	121.8	51.9	252
	Difference necessary for significance			31.2	Not significant	Not significant	Not significant

[1]Paper No. 224, Department of Vegetable Crops, Cornell University, Ithaca, New York.

TABLE II—EFFECT OF MINERALS AND GROWTH PROMOTING SUBSTANCES EMPLOYED AS STARTER SOLUTIONS ON THE YIELD AND STAND OF CAULIFLOWER AND THE YIELD OF BRUSSELS SPROUTS GROWN ON SASSAFRASS SILT LOAM SOIL ON LONG ISLAND

Treatment	Cauliflower		Brussels Sprouts
	Plants/A	Crate*/A	Yield Quarts**/Acre
Minerals†	5465	385	5797
No Minerals	6197	386	6597
Difference necessary at 5 per cent point	554	Not significant	Not significant
Growth promoting substance			
Indole Acetic (0.02 ppm)	5980	371	5964
Indole Proprionic (0.02 ppm)	5445	368	5520
Indole Butyric (0.02 ppm)	6197	413	6502
Napthyl Acetic (0.02 ppm)	6593	459	7738
Water (control)	6593	457	6605
Manure extract (0.1 per cent Acetic)	6771	450	7484
V. C. (0.02 ppm)	3208	179	3556
Difference necessary at 5 per cent point	1049	103	2154

All interactions of minerals ×growth promoting substances were insignificant.

*Crate equals 12 U. S. number 1 heads cauliflower.
**Quart equals 1.25 pounds Brussels sprouts.
†Shives best solution expressed as commercial fertilizer by mixture of nitrate of soda, superphosphate, muriate of potash and lime.

From this table it can be seen that although the stand of cauliflower was reduced by minerals the yield was not altered. With Brussels sprouts the yields were statistically the same. The facts that no growth promoting substance gave any better yields than water and that there was no differential response with or without minerals lead to the conclusion that the use of minerals with or without growth promoting substances is of no benefit for cauliflower. The same conclusion follows for Brussels sprouts. In fact any response to the solutions which was significant was in a deleterious direction.

From these results the conclusion may be obtained that water is as beneficial a transplanting solution for cauliflower and Brussels sprouts as has been tried to date and no recommendation can be made to alter the present practice. The reason for the divergence of these results from those reported elsewhere might be the fact that these crops on Long Island are grown with a high level of fertility and thus respond little to additional readily available nutrients applied at planting time.

Studies of the Response of Lettuce to Manure and Commercial Fertilizers

By ALBERT E. GRIFFITHS, *University of Arizona, Tucson, Ariz.*

NUMEROUS fertilizing materials are available to lettuce growers. In choosing the correct fertilizer or combination of fertilizers, consideration should be given to the physical and chemical condition of the soil; the crop to be grown; the economy of production; and, the effect on a long time fertility program.

Previous investigations (5) have definitely demonstrated the value of phosphorus and nitrogen in the production of lettuce on the alkaline soils of Arizona. In a general way certain fertilizer materials have been more efficient than others. However, results with the same materials have tended to vary from season to season, and from farm to farm.

This report presents preliminary data on the use of various commercial fertilizers and manure on lettuce grown on raised, irrigated beds in the Salt River Valley.

METHODS

The experiment was laid out on the University of Arizona Farm at Mesa in the late summer of 1940. The soil had an average pH of 8.0, and is classified as a Laveen clay loam. No organic matter had been incorporated for at least 3 years prior to 1940, and the plots had been continuously cropped to grain. The land was somewhat puddled and in uniformly poor condition.

On August 12 one half of the entire plot of 1¼ acres received 10 tons per acre of a partially decomposed corral manure. The manure was thoroughly incorporated in the soil, and the entire plot was irrigated twice before the lettuce was planted on September 12. Soil tests made in the first foot at time of planting indicated 12 parts per million of PO_4 and 15 parts per million of NO_3 on the manured plot as compared with 6 and 11 parts per million respectively on the non-manured plots.

Commercial fertilizers were band placed at time of planting. The bands were 1½ inches on the furrow side of the seed row and 3 inches below the row (3). No side dressings were employed. The following table indicates the fertilizer treatments and rates of application:

	Pounds per acre
Calcium nitrate	100
Treble superphosphate	160
Ammonium-phosphate (11–48)	150
Calcium metaphosphate plus ammonium sulfate	190
A2 mix (¼ N from bloodmeal; ⅛ from $CaNO_3$; ⅛ from urea;— ½ from ammonium-phosphate, 16–20)	290
G2 mix (Same as A2 mix except ¼ N supplied by dried, fine-goatmanure in place of bloodmeal)	600
Commercial 11–22 plus treble superphosphate	250
Check — No fertilizer	—

All fertilizers were applied so that each replicate received approximately 16 pounds of nitrogen per acre, and/or 72 pounds of phosphorus per acre (2). Each treatment was replicated three times on both the manured and non-manured plots. Each replicate was a single bed 280 feet long by 3½ feet wide. The replicates were randomized in order that results might be analyzed by the variance method.

The lettuce was a pure line strain of Imperial 152. It was planted September 12, irrigated up September 13, and thinned to stand 12 to 15 inches in the row October 8. Each bed had two rows in accordance with commercial practice. The first harvest was on December 18, the second and last on December 28.

Plant samples for chemical analysis were taken on October 7 and 21, November 11 and December 28. On the first two dates of sampling 10 plants were taken from each replicate. On the last two dates four plants were taken from each replicate.

Results and Discussion

Table I presents the yields in total crates per acre, and also the effect of the treatments on maturity as indicated by the number of crates

TABLE I—The Effect of Manure and Commercial Fertilizers on Lettuce Yields

Treatment		Crates Per Acre		Total Yield (Crates Per Acre)	Pack Out (Per Cent)	L.D. 19:
		Cut I	Cut II			
Calcium nitrate	M	148	56	204	62	
	NM	49	87	136	52	Between total yields—6 crates
Treble-phosphate	M	172	79	251	75	
	NM	72	71	143	56	
Ammo-phos (11–48)	M	169	102	271	80	Between yields within cuts—11 crates
	NM	65	101	166	62	
CA metaphosphate and ammonium sulfate	M	177	42	219	65	
	NM	68	85	153	58	Between cuts—11 crates
A2 Mix (9–26)	M	179	75	254	75	
	NM	76	111	187	71	
G2 Mix (4–12)	M	167	81	248	73	
	NM	96	90	186	69	
11–22 and treble-phosphate	M	173	59	232	68	
	NM	96	76	172	66	
No fertilizer	M	157	64	221	67	
	NM	52	99	151	58	

harvested at first and second cuts. A word of explanation is necessary concerning the term "per cent pack-out". Heretofore the term has been used to indicate the per cent of total "cut-out" actually packed. In this study it has seemed more logical to consider the term as applying to total number of crates packed, based on the actual number of heads in the field at time of harvest. Thus the difference between the percentage given and a theoretical 100 per cent applies to all non-marketable lettuce regardless of the cause.

From Table I it is apparent that yields on the manured plots are

significantly greater than on the non-manured plots for all commercial fertilizer treatments. The greatest difference between manured and non-manured plots occurred within the treble superphosphate treatment (108 crates), closely followed by the 11–48 ammonium phosphate treatment (105 crates).

Ammonium phosphate (11–48) returned a significantly higher yield than any other treatment when used on manured plots. However, it was closely followed by the A2 (bloodmeal) mix, treble superphosphate and the G2 (goatmanure) mix. Although the differences between these three treatments and 11–48 ammonium phosphate are statistically significant, from a commercial standpoint it is possible that no advantage in yield could be claimed for one over any of the others. However, from the standpoint of price per unit of plant food it is probable that the most economical fertilizer on manured land, under the conditions of this experiment was treble superphosphate closely followed by 11–48 ammonium phosphate.

On the non-manured plots the A2 and G2 organic mixes were significantly superior to all others. From a commercial standpoint it is probable that little advantage could be claimed for these two mixes over the commercial 11–22 plus treble superphosphate, and 11–48 ammonium phosphate. Treble superphosphate alone on the non-manured plots gave yields not significantly different from the no fertilizer check. This indicates that nitrogen was a more limiting factor than phosphorus on the particular soils involved in this experiment. The fact that all plants on the phosphate plots on non-manured land were more chlorotic than those found in any other treatment tends to substantiate this interpretation.

Calcium nitrate is the most used single source of nitrogen in commercial lettuce production in the Salt River Valley. Although it has been demonstrated that calcium nitrate is not a highly effective source of nitrogen, the material is in general use because no sodium is included. Many soils in the Salt River Valley contain relatively large amounts of "black alkali" or sodium carbonate. It has been considered that the use of sodium nitrate tends to increase the quantity of "black alkali". Ammonium sulfate has not been applied extensively because single sources of nitrogen have been used as side-dressings during cool weather, when immediate nitrogen availability was desired. In view of the present difficulty of obtaining calcium nitrate, and in the light of recent tests indicating that nitrogen in the ammonia form is nearly as rapidly available as in the nitrate form, larger quantities of ammonium sulfate will be used in the future.

On both manured and non-manured plots calcium nitrate alone resulted in yields depressed below those obtained in the check treatment. The plants were of good color but grew slowly throughout the season. Other investigators (4) have also noted that lettuce gave low yields when fertilized with nitrogen alone, and have explained it by stating that phosphorus was more limiting than nitrogen. This was probably the case on the non-manured plots in the present study. On the manured plots, however, it is difficult to explain the difference on this basis. Soil analysis not presented here indicate that available phos-

phorus on the manured plots was sufficiently high for normal growth of the lettuce plant. It is possible, however, that the relatively high plane of nitrogen nutrition may have caused phosphorus to become limiting at a relatively high level. The fact that lettuce often responds to phosphatic fertilizers, even though available phosphate is high, has been observed many times under commercial conditions.

The treatment involving the use of calcium metaphosphate and ammonium sulfate was included primarily to test the action of a material relatively new to agriculture. Calcium metaphosphate plus ammonium sulfate did not significantly increase the yields on either the manure or non-manure plots over those obtained on the check treatment.

In every fertilizer treatment a significantly greater proportion of the total yield was taken at the first cut on manured land. On non-manured land a higher proportion of the total yield was taken at the second cut for five treatments. Treble superphosphate and the G2 mix gave no significant differences between cuts, while commercial 11–22 gave a higher yield at first cut. It is apparent from this study that a manure application of 10 tons per acre tended to hasten the maturity of lettuce under the conditions of the experiment. The same results, but to a lesser degree were obtained by band placing goat manure mixes.

Highest percentage pack outs were obtained from ammonium phosphate (11–48), treble superphosphate, A2 mix and G2 mix on manured plots, and from A2 mix, G2 mix, commercial 11–22 and ammonium phosphate (11–48) on non-manured plots. Percentage pack outs for the organic base fertilizers on non-manured plots were only slightly lower than for ammonium phosphate (11–48) and treble superphosphate on manured plots.

For both inorganic and organic base fertilizers, total yields were much greater on the manured plots. On the non-manured plot organic base fertilizers produced a greater yield than the inorganic "simples". When both manured and non-manured plots are averaged, we find that the organic base fertilizers have given a consistently greater yield. However, the difference amounts to but slightly over 13 crates. Statistically such a difference might be significant, but commercially it probably is not. One must consider the higher unit cost of the organic base mixes in addition to the greater rates of application necessary to achieve results comparable to those obtained from a lesser amount of the inorganic base fertilizers.

Fig. 1 graphically presents the phosphorus and nitrogen uptake for all treatments on the manured and non-manured plots. No attempt has been made to differentiate between the various fertilizers due to lack of statistical significance between the composition of plants from different treatments. The material is presented on the basis of milligrams per plant rather than as a percentage dry weight basis, in order to show more clearly, actual differences per plant in absolute amount of the two chemicals.

In general, at harvest time, lettuce plants from manured plots contained more phosphorus and nitrogen than plants from non-manured

plots. In addition, a higher level of the two nutrients was maintained throughout the entire growing period, reflecting a more rapid growth rate and nutrient intake on manured land.

In respect to the individual treatments certain trends may be observed. The most rapid rate of uptake of phosphorus and nitrogen, on both manured and non-manured plots occurred when ammonium phosphate (11–48), A2 and G2 mixes were used. Lowest rate of uptake occurred on the no fertilizer check. The most rapid period of nutrient uptake and plant growth occurred between October 21 and November 11. The increase in rate was more marked on the manured plots than on the non-manured plots.

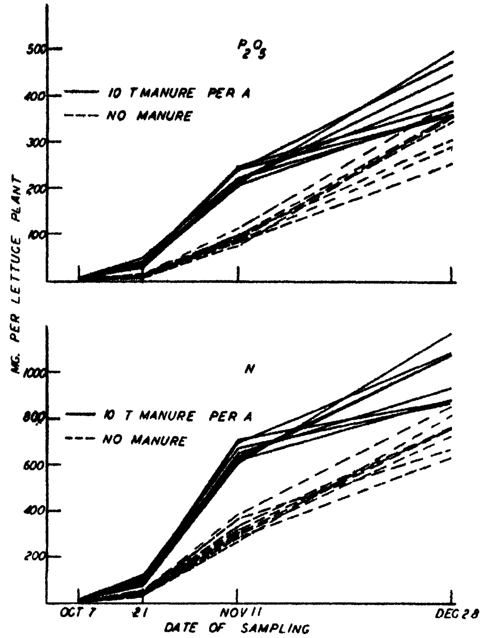

FIG. 1. Effect of manure on the phosphorus and nitrogen in lettuce.

It has been pointed out (1) that the addition of manure to soil, at the rate of 10 tons per acre, increases the water-holding capacity and improves the general physical condition of some soils. In the present experiment the manured plots were in noticeably better physical condition at time of planting than the non-manured plots. Throughout the growing season water penetration was more rapid and uniform than in non-manured plots. Soil moisture tests made just before irrigations, in the top 8 inches, were consistently 2 to 3 per cent higher than on non-manured plots. These differences alone could account for much of the increased growth, increased nutrient uptake, and larger total yields observed on the manured plots. However, manure or other organic materials may influence growth in so many ways that it is difficult to assign a definite reason for specific results of its use.

SUMMARY

Under the conditions of this experiment with a fall crop of lettuce, ammonium phosphate (11–48) gave the highest total yields of lettuce on land receiving 10 tons per acre of manure. On land receiving no manure highest yields were returned from an experimental mix of approximately 9–26 analysis, and providing one fourth of the nitrogen from bloodmeal.

In general, the simple, inorganic sources of plant nutrients gave

best results on the manured plots, while fertilizers in which a part of the nitrogen was contributed from organic sources gave best results on non-manured plots.

Applications of 10 tons of manure per acre resulted in more rapid growth, more rapid intake of phosphorus and nitrogen, earlier maturity, and a more succulent product.

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Effects of Synthetic Growth Substances on Transplants

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WHEN this work was initiated, little was known concerning the varietal response of various woody and herbaceous plants to Transplantone and other synthetic growth substances. Therefore, preliminary experiments were undertaken to study varietal response, effect of concentration and methods of application. Since most of the experiments are rather fragmentary, specific results are to be accepted only as indications. It is well known that many factors contribute to success or failure in the use of synthetic growth substances.

OUTSIDE EXPERIMENTS

Lonicera fragrantissima:—The first transplant experiments consisted of preliminary tests with rooted cuttings. Since summer cuttings of *Lonicera fragrantissima* are well rooted before they start any shoot growth, this species was chosen. On August 12, 1939, similar lots of 10 each were treated with various growth substances in a talc mixture by merely inserting the bunch of cuttings in a small paper bag containing the desired mixture and shaking so that the roots were well coated with the dust. Two identical sets were so handled, one placed in pots in the cold frame and the other planted directly in beds in a lath house. Some of the substances used were Transplantone No. 1, Nicotinic acid 1–1000 and Thiourea 1–20,000. The top growth of the different lots was measured 2 months after treatment. Positive results were obtained only with the plants placed directly in the beds. Nicotinic acid was the most effective substance used, producing on the average 75 per cent more top growth than the untreated lot produced.

Malus sieboldi arborescens:—On October 6, 1939, seedlings of *Malus sieboldi arborescens* were transplanted from beds to nursery rows. Lots of 10 plants each were treated with talc mixtures, sparingly applied to the moistened roots with a small sulfur duster. The talc mixtures used were nicotinic acid 1–500 and 1–1000, indolebutyric acid 1–5000 and Transplantone No. 1. One lot was also soaked in a 1–1,000,000 solution of vitamin B_1 for 15 minutes.

Thus far the results are more or less preliminary. The lots showing the most growth were dusted with Transplantone and indolebutyric acid. The roots of plants so treated showed the clustering of new branch roots at the place where the main roots were cut at the time of transplanting. Like effects have been reported by P. E. Tilford (1) and L. C. Chadwick (2) as a result of using the method of soaking plants in a solution of synthetic growth substances. It is significant that the dusting method produces the same effect with greater ease of application and less waste of material, especially important with larger plants. Neither the nicotinic acid nor the vitamin B_1 treatments produced the clustering of roots.

INSIDE EXPERIMENTS — GRAFTING STOCK

Picea canadensis and *Juniperus virginiana:*—Spruce and juniper seedlings had been potted the middle of December, and since they were

slow in becoming established, various treatments were applied on January 16, 1940, to lots of 25 or 50 plants as follows: Transplantone No. 3 applied once at the rate of 1¼ teaspoonful per gallon of water and then drenched an hour later with tap water; Transplantone No. 3 applied at the rate of ¼ teaspoonful per gallon of water and then followed by like applications January 23 and January 30; naphthaleneacetic acid mixed with talc and sugar in the proportion of 1 part of the acid to 200 parts of talc and 24,800 parts of sugar, applied at the same rates and times as the Transplantone. A control lot was also included.

On March 1 the plants were removed from the pots and the root development observed. All treated lots showed greater development of absorption roots than the control lot. The treatment consisting of three weekly applications of Transplantone No. 3 was the most effective. The junipers displayed a more marked response than the spruces. On the date observed, only 5 junipers in a lot of 25 controls were ready for grafting while 11 in a lot of 25 plants given the three weekly treatments with Transplantone No. 3 were ready. The relatively poor proportion of plants ready for grafting was undoubtedly due to damage to the stock in shipping. However, the results indicated that the use of Transplantone may be particularly valuable for the treatment of stock that has been potted only a month or two before grafting.

Inside Experiments — Perennials

On January 7, 1940, seedlings of several varieties of perennials were shifted to flats and soaked with various solutions containing synthetic growth substances. One hour later they were watered with tap water. The plants used were *Anthemis kelwayi*, Coreopsis Double Sunburst, Delphinium Blackmore, *Incarvillea delavayi*, *Viola Chantreyland*, and *Heliopsis pitcheriana*. Duplicate treatments were given to Coreopsis and Viola planted in soil with high N P K, about 50–20–30 as opposed to 10–5–10. The treatments consisted of Transplantone No. 3 applied at the rate of 1 teaspoonful per gallon of water and naphthaleneacetic acid 1–25,000 applied at the same rate.

The plants were grown in the flats until February 16, a period of nearly 6 weeks. At this time observations were taken and the plants transferred to 3-inch pots. The plants grown in soil with medium N P K were definitely superior to the plants grown in soil with high N P K. The plants of *Anthemis kelwayi* that had been treated with Transplantone were somewhat larger but weaker and more sprawling in habit than the controls. The plants of *Heliopsis pitcheriana* that had been treated with Transplantone exhibited a much more even development than the plants in any other lot, but there were too few plants to draw any definite conclusion. The other varieties exhibited no noticeable response to treatment.

On February 19 the 20 best plants of Anthemis, Coreopsis, Incarvillea and Viola in the flats with the medium N P K soil mixture were placed in 3-inch pots. Each lot in flats was divided into two lots of 10 plants each. One of these lots was retained as a control. The other lot if treated with Transplantone in the flat, was given continued

treatments consisting of weekly waterings with Transplantone No. 3 at the rate of 1 teaspoonful per 10 gallons of water. If treated with naphthaleneacetic acid in the flat the acid mixture was applied at the rate of ½ teaspoonful per gallon of water. This part of the experiment was set up to find the effect of continued treatments.

April 2, after six weekly treatments, the five best plants were chosen from each lot, the tops severed from the roots, and the fresh weights of both tops and roots recorded. After the tops and roots had attained the air-dry condition, the dry weights were recorded.

According to previous reports, synthetic growth substances are more effective in increasing the fresh weight of plants than in increasing the dry weight. An analysis of the results, in general, substantiates these reports. With Coreopsis, the only marked increase was in the fresh weight of the lot treated with naphthaleneacetic acid. With Incarvillea, the lot treated with the acid showed increase in both fresh and dry weights, but the lot treated with Transplantone showed marked increase only in the fresh weight. With Viola, the Transplantone increased both fresh and dry weights considerably but the acid was detrimental. Anthemis kelwayi showed no benefits from treatment.

Considering Coreopsis, Viola and Incarvillea, all of which were somewhat stimulated by treatment, Coreopsis responded favorably to the continued use of both substances, based on dry weights. With Viola, the effects of continued treatment were negative. With Incarvillea, the continued use of naphthaleneacetic acid was effective but the continued use of Transplantone was of little advantage. Due to experimental error, these results can be accepted only as indications.

In a minor experiment, the combined effect of seed treatment and subsequent seedling treatment was studied. Seeds of *Anthemis kelwayi*, Pyrethrum James Kelway and *Dianthus alpinus alwoodi* had been treated with indoleacetic acid and naphthylacetamide by coating the seeds with talc mixtures, 1–2000. Plants from treated and untreated seed were included in the same Transplantone treatment schedule as outlined for the other perennials in pots. In considering the dry weights of tops and roots together, no marked differences were noted with Anthemis. With Pyrethrum, the only marked effect of treatment with Transplantone was with the lot grown from seeds that had been treated with indoleacetic acid. With Dianthus, treatment with Transplantone nearly doubled the dry weights with the exception of the lot that had been grown from seed that had been treated with naphthylacetamide. This lot was actually inferior to the controls.

Concentration and Re-treatment

Results from other minor experiments can only be summarized. In order to check on optimum concentrations, various concentrations of Transplantone and naphthaleneacetic acid were applied to seedling tomato plants in pots for four successive weeks. The greatest stimulation in growth resulted from treatments with Transplantone at the rate of 1 teaspoonful to 10 gallons of water and naphthaleneacetic acid at the rate of 1 part to 50 million parts of water. However, no differences were apparent when the plants had come to maturity in the field.

The same watering procedure was used with seedlings of a wilt-resistant aster. Two spray treatments with naphthaleneacetic acid, 1–10,000 and 1–100,000, were checked against the watering method. Although Transplantone stimulated growth to some extent, the most marked stimulation resulted from the 1–10,000 solution of naphthaleneacetic acid sprayed on the foliage. These results were based on wet and dry weights of roots and tops.

In order to check on the effects of continued weekly treatments with Transplantone, various concentrations were applied in one to five weekly treatments on rooted cuttings of *Juniperus chinensis pfitzeriana* after potting. The greatest effects of treatment were on survival. The results indicated that successive treatments are of little benefit. Also, Transplantone at the rate of 1 teaspoonful to 10 gallons was just as effective as at the rate of 1 teaspoonful to 1 gallon.

Conclusions

Treatment with synthetic growth substances stimulated root and stem development of woody plants such as fragrant honeysuckle, crab-apple and pfitzer juniper; of some perennials, namely, Coreopsis, Viola and Incarvillea; and of annuals such as tomato and aster. The direct application of talc mixtures of certain synthetic growth substances to the moistened roots of small trees resulted in the production of abnormal clusters of branch roots. However, the practical advantage of treatment is not yet assured. The watering of grafting stock with solutions containing synthetic growth substances resulted in lower mortality and a more rapid development of absorption roots, particularly with red cedar. In studies with Pyrethrum and Dianthus, some relation was found between seed treatment and subsequent transplant treatment. Applications of Transplantone at the rate of 1 teaspoonful per 10 gallons of water is apparently optimum for most plants.

Literature Cited

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A Simplified Method of Determining the Date of Bud Formation in Short-Day Crops

By Roger Clapp, *University of Maine, Orono, Me.*

TO RETARD or to hasten the bloom of plants which receive their flowering response from a decreased photoperiod (day length), it is necessary to know at what date the normal day length is short enough to induce flowering.

Previous work by Post (1) has shown that bud formation occurs at very nearly the same date each year. Knowing this date the commercial grower may calculate the time at which he wishes to darken his crop for flowering ahead of normal or the date at which he must apply additional night illumination if he wishes to hold the crop back.

Post (1) proposed a method of determining the date of bud formation in which portions of the crop were placed under short day conditions at given intervals. If a plot was darkened after the days had already become short enough for bud formation, this plot would flower at the same time as the untreated check. The plots darkened ahead of the time when the days were short enough to induce flowering would bloom ahead of the check. He took as date of bud formation that plot which bloomed at the same time as the check.

In the simplified procedure now described supplementary illumination is applied to the crop near the time when the days are becoming short enough for normal bud formation. At given intervals a portion of the crop is returned to normal day length. If the normal day length is still too long for bud formation this plot will flower at the same time as the check, but if a plot is returned to normal day length after the days have become short enough to induce bud formation, this plant will flower later than the check. By this method the normal date of bud formation may be located to within a 2- or 3-day period. These dates are easily determined as the check and those plots not retarded by being held under light show color and come into bloom all at the same time, while those retarded by being held under a long-day condition when the normal day length was short enough for bud formation, will show less development and bloom later. The investigator can read his results by one observation just before the crop comes into bloom.

Sixty watt Mazda lights are suspended over the crop in the usual method employed to retard the flowering of chrysanthemums, and run for 2 hours after dark. Where the period covered by test is more than 1 month, a longer nightly illumination period will be needed. A screen of black sateen or other darkening cloth is suspended across the bench so as to exclude from the light two cross rows of the crop to serve as check. Each period—2, 3 or more days as desired for the test intervals—two more rows are returned to normal night exposure by moving the screen forward two rows so as to prevent the supplementary illumination from reaching this portion any longer. At the termination of each period additional plants are returned to the normal night length. When a reasonable spread has been covered, the light and screening are removed. As the crop comes into bloom it will be very evident at what date the days became short enough for bud formation.

TABLE I—NORMAL DATE OF BUD FORMATION OF THE GREENHOUSE CHRYSANTHEMUM AT ORONO, MAINE, 45 DEGREES NORTH LATITUDE

	1937*		1939**		1940†	
	Date Bud Set‡	Check Bloomed	Date Bud Set	Check Bloomed	Date Bud Set	Check Bloomed
Pompon Varieties						
Blanche (Anemone)	———	———	Aug 30-Sep 2	Nov 10	Sep 1-4	Nov 10
Bronze Popcorn (S. Pomp).	After Sep 5	Nov 5	———	———	———	———
Cora Peck Buhl (Int. Pomp)	———	———	———	———	Sep 1-4	Oct 22
Izola (Anemone)	———	———	———	———	Sep 1-4	Nov 8
Jewell (S. Pomp)	———	———	———	———	Sep 1-4	Oct 21
Melba (Single)	After Sep 5	Nov 8	Aug 30-Sep 2	Nov 8	Sep 4-7	Nov 9
New York (S. Pomp)	After Sep 5	Nov 9	Aug 30-Sep 2	———	Sep 4-7	Nov 5
Nuggets (S. Pomp)	———	———	Sep 2-5	Nov 5	———	———
Pink Popcorn (Int. Pomp).	———	———	———	———	Sep 1-4	Nov 6
Sea Gull (Int. Pomp)	———	———	———	———	Sep 4-7	Nov 11
Standard Varieties						
Ambassador	———	———	Aug 30-Sep 2	Nov 3	Sep 1-4	Nov 1
Detroit News	———	———	Aug 30-Sep 2	Nov 3	Sep 1-4	Nov 1
Gladys Pearson	———	———	Sep 5-8	Nov 20	———	———
Mrs. H. E. Kidder	———	———	Aug 30-Sep 2	Nov 5	Sep 1-4	Nov 6
Mefo	———	———	Sep 2-5	Nov 10	———	———
Monument	———	———	———	———	Sep 4-7	———
White Distinction	———	———	Sep 5-8		———	———
Yellow Monument	———	———	Sep 2-5	Nov 10	———	———

*Lighted Aug 16 with 10 day intervals.
**Lighted Aug 25 with 3 day intervals.
†Lighted Aug 29 with 3 day intervals.
‡Commercial crop was very late blooming in New England this season.

Work with chrysanthemums and stevia has shown that the observations should be made just as the buds of the check show color. The size relation between the buds is very obvious, whereas it is rather difficult to differentiate between the partially opened and the fully opened flowers.

Using this procedure, Table I shows that the normal date of bud formation for the greenhouse chrysanthemum is September 1 to 7 at Orono, Maine, near the 45th parallel of north latitude. The date of bud set this year for stevia (*Piqueria trinervia*) was October 5 to 8 for the crop which bloomed December 12.

The position of the crop in relation to north latitude is important because in August and September the days are longer at Orono, near the 45th parallel, than at places further south. Post (1) found that at Ithaca, N. Y., near the 42nd parallel the chrysanthemums set their buds August 15 to 25 and stevia September 20 to 27.

LITERATURE CITED

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The Effects of Fertilizers, Organic Material and Irrigation on the Yield of Certain Truck Crops

By L. M. Ware, *Alabama Experiment Station, Auburn, Ala.*

THE results reported here are taken from an experiment only well started. The results, however, follow such a common pattern and seem to have such an important bearing on the setting up in the future of certain types of experiments, especially those dealing with irrigation, that a preliminary report is made at this time.

The experiment began in the spring of 1938. A succession consisting of two spring, two summer, and two fall crops has been planted each year in each of two similarly treated sections. Concrete bins were constructed for the experiment and the top 8 inches of soil in each bin was distributed equally throughout the series of 60 bins and the soils in each bin composited. Treatments were duplicated. Six plots receiving 1,000 pounds per acre of fertilizer but receiving no organic material or irrigation were used as checks. Water was supplied from the city system at the rate of 1 inch per week when rain did not supply approximately this quantity. The organic material was introduced by supplying 3 tons per acre of dried *Lespedeza sericea* before each of the three crops in 1938 and 1939 and by supplying 2 tons before the spring and fall crops in 1940. In plots marked "V" hairy vetch, was grown in position except for the 1938 spring crops when 3 tons per acre of sericea were introduced. In the fall of 1938, vetch occupied the bins, necessitating the loss of the fall truck crop; in 1939 and in 1940 vetch was planted at the last cultivation of the fall truck crop, making possible the planting of vetch in addition to the three truck crops within a year's time in the vetch plots. Cowpeas were grown in position at the sacrifice of the summer truck crop. To obtain a satisfactory initial stand of vegetables, light irrigation was supplied to all plots until the seedlings were up and reasonably well established.

The amount of rainfall has varied considerably during the several growing seasons. The spring season of 1938 was characterized by adequate and fairly uniformly distributed rainfall while the fall season had a shortage of rainfall during the first half of the growing period but abundant rainfall during the second half. The spring season of 1939 was characterized by a total rainfall only slightly under normal, although there was a period of low rainfall during the first 3 weeks of April and also during the last 3 weeks of May. The fall season of 1939 was a very dry season, only about 1 inch of rain falling between the first week of October and the first week of December. The spring of 1940 was characterized by adequate rainfall in March, a shortage of rainfall during the last 3 weeks of April and a like shortage for the corresponding weeks in May. In 1940 there was no appreciable rainfall between the first week of September and the first week of November.

The spring crops of beans and potatoes were harvested each year about the first week of June except the potatoes in 1940 which were harvested the last week of June. Turnips have been harvested each year during the latter half of November and the first week of Decem-

TABLE I—Yields of Truck Crops Receiving Different Rates of Fertilizers with Organic Matter and Irrigation Supplied Singly and in Combinations

Irrigation (Inches Per Wk.)*	Organic Material	1938 Rate of Fertilizer Applied† (Bu. Per Acre)		1939 Rate of Fertilizer Applied (Bu. Per Acre)		1940 Rate of Fertilizer Applied (Bu. Per Acre)	
		500 Pounds	1000 Pounds	500 Pounds	1000 Pounds	500 Pounds	1000 Pounds
		Potatoes (Spring)					
0	O	161	181	72	106	37	71
1	O	127	175	67	95	45	84
0	Lesp**	149	169	103	120	137	166
1	Lesp	150	189	161	179	200	266
1	V**	—	160	—	—	—	340
1	S**	—	209	—	195	—	131
0	O	—	179	—	138	—	82
Acre inches—water added		-		7		4	
Standard error of 6 check plots		6.2 bu. per acre		7.0 bu. per acre		7.9 bu. per acre	
		Beans (Spring)					
0	O	131	199	46	105	5	18
1	O	105	165	74	81	29	54
0	Lesp	110	172	127	157	76	82
1	Lesp	97	137	137	136	135	188
1	V	—	168	—	189	—	262
1	S	—	199	—	111	—	84
0	O	—	206	—	100		21
Acre inches—water added		-		5		4	
Standard error of check plots		17.9 bu. per acre		6.1 bu. per acre		2.79 bu. per acre	
		Turnips (Roots + Tops) (Fall)					
		(Lbs. Per Acre)		(Lbs. Per Acre)		(Lbs. Per Acre)	
0	O	4393	6843	10573	14153	2304	4360
1	O	7260	10192	15956	21233	8376	14415
0	Lesp	8757	11418	16218	16798	10684	11137
1	Lesp	10898	13158	24597	30363	18664	22254
1	V	—	—	—	25988	—	18399
1	S	—	15030	—	28603	—	13624
0	O	—	8213	—	13592	—	4202
Acre inches—water added		-		6		8	
Standard error of check plots		451 lbs. per acre		491 lbs. per acre		379 lbs. per acre	
		Onions (Fall and Winter)					
0	O	1820	2523	599	1225	Crop not harvested at this time	
1	O	1481	2575	726	2552		
0	Lesp	2650	3737	2797	3352		
1	Lesp	2431	4155	3425	4230		
1	V	—	—	—	2754		
1	S	—	2810	—	2827		
0	O	—	2393	—	1093		
Acre inches—water added				8			
Standard error check plots		96.7 lbs. per acre		114 lbs. per acre			

*Irrigation was 1 inch per week if rain did not supply approximately this amount.
**Lesp = Lespedeza;
V = Vetch grown in position;
S = Cowpeas grown in position.
Organic material was turned 10 days to 2 weeks before planting if green and 2 weeks or more if dry.
†Fertilizer analysis 6–8–4.

ber. Onions have been harvested in March following the fall planting. The results are tabulated separately for each year because each set of records must be interpreted in the light of factors affecting yields for a given year.

Three years records are reported for two spring crops and one fall crop; two years records are reported for the other fall crop.

With adequate rain for the season as a whole and with no organic "build-up" in the soil, no benefit resulted from the use of either organic matter or of irrigation at either rate of fertilizer application for either of the 1938 spring crops.

The general character of the results since the spring of 1938 permits a rather simplified summarization: while irrigation and organic matter each used singly have given slight to large increases in yield, it has been only when a combination of the two has been used that maximum increases have been obtained.

In 1939 and 1940 only small increases in yield were obtained for irrigation alone with the two spring crops and with onions. A material increase, however, was obtained for irrigation with fall turnips each of the three years. The fall seasons have been characterized by long periods of drought. Onions were planted in the fall but harvested in the spring. Winter and early spring rains have supplied good moisture for onions. Supplementary experiments have shown no increase in yield for 2 inches of irrigation per week over 1 inch.

Organic material used alone has given much greater increases in the yield of beans and potatoes in the spring than irrigation alone. This has also been true with onions in the fall and with one of the three crops of fall turnips. Irrigation alone has given greater increases with the other two crops of turnips than organic material alone.

All crops with the exception of the spring crops for 1938, which were grown under favorable moisture conditions supplied by rain, and beans for 1939 have shown marked increases in yield, both relative and absolute, from the use of a combination of organic material and irrigation. In 1939, while neither irrigation nor organic material gave a significant increase in the yield of potatoes, an increase over the check of 73 bushels per acre (69 per cent increase) was obtained at the 1,000 pound rate of fertilizer application with a combination of the two treatments. In 1940, irrigation alone gave no significant increase in the yield of potatoes. Organic matter alone gave an increase of 95 bushels per acre (134 per cent increase) whereas a combination of the two treatments gave an increase of 195 bushels per acre (274 per cent increase). The same general results were obtained for the combination with beans in 1940 although small but significant increases were obtained for both irrigation and organic material when applied singly.

While relatively greater increases were obtained in the yields of fall crops than of spring crops by the use of irrigation and organic material used singly, yet a combination of the two was required for maximum or even near-maximum yields of fall crops. Thus during the dry fall of 1939 the yield of turnips was increased 7,080 pounds per acre by irrigation, and increased 2,645 pounds per acre by organic matter but the increase from a combination of the two was 16,210 pounds per acre. Similar results were obtained the other two years.

It would appear obvious from the evidence presented that irrigation experiments planned without proper regard to the influence of certain fertility factors might fail in determining the value of irrigation. At

low fertility levels, irrigation might fail to give increases justifying the additional cost of the operation; at high fertility levels the increases might easily justify the extra cost.

The results cited so far have dealt with introduced organic matter. Practical and inexpensive methods of providing organic material becomes of high importance since organic material appears so necessary in obtaining maximum yields. In the treatments marked "V" and "S" the organic material has been grown on the plots. In the vetch (V) plots as now handled, three truck crops are grown each year in addition to the vetch although the date of planting of Irish potatoes in the spring is delayed. In the summer legume plots (S) cowpeas are grown during the summer months, thus necessitating the loss of the summer truck crop.

Since the present system of handling vetch has been established, records have been obtained on one crop of potatoes and two crops of beans as spring crops and two crops of turnips as a fall crop. The yields of the spring crops on the vetch plots have been the highest of all treatments. In 1940 a yield of 340 bushels of potatoes per acre was produced with vetch as compared to a yield of 266 bushels for the corresponding treatment with the organic material introduced. With beans the corresponding yields were 262 and 188 bushels per acre in 1940 and 189 and 136 bushels per acre in 1939. The yields of fall turnips in 1939 and in 1940 on the vetch plots after two crops had been grown since the turning of the vetch was quite satisfactory although not as high as the yields on plots receiving the introduced material. On a commercial scale, a method of removing the fall crop without injury to the young vetch has yet to be developed.

Cowpeas grown in position have given significant increases in the yield both of fall crops immediately following and of the spring crops grown the following year although cowpeas have given much smaller increases than vetch with the spring crops.

Limits in the Use of Borax in the Production of Certain Vegetable Crops

By R. H. White-Stevens, *Cornell University, Ithaca, N. Y.*

Abstract

This material will be published in full in a publication from Cornell University.

BORON deficiency has been found to be a serious problem in the production of certain vegetable crops on the soils of Long Island. The crops that have been found to be most seriously affected by the deficiency are cauliflower, rutabagas, table beets, mangolds and radishes. In all these crops definite visible symptoms of boron deficiency have been found in commercial plantings, and successful control of these symptoms has been attained by inclusion of borax in the fertilizers applied. For the above mentioned crops, at least 10 pounds of borax per acre are required to correct the deficiency, and under certain conditions as much as 15 to 20 pounds of borax per acre have been required for adequate control of the deficiency.

Other crops which have shown increased yields in response to the application of borax are potatoes and peas, particularly when grown on soils which have produced cauliflower showing boron deficiency symptoms. Yields of these crops were increased by the application of 5 pounds of borax per acre. Applications in excess of this amount tended to reduce yields of these crops, particularly if repeated for several years.

Snap beans, Lima beans, spinach, and carrots did not show increased yields from the application of borax up to 5 pounds per acre. Amounts in excess of this tended to reduce yields, marked reduction being effected from applications of 20 pounds of borax per acre.

Sweet corn was unaffected by applications of borax varied from nil to 20 pounds borax per acre.

Studies of the interaction of the incidence of boron deficiency of susceptible crops, in relation to borax applied and season, showed that in wet years higher rates of borax application were required than in dry seasons. This fact is undoubtedly related to the low soil reaction of these soils. Adequate control could be maintained by applying the amounts required for a dry season at planting, and in the event of subsequent excessive rainfall additional quantities of borax could be applied as side dressings with sodium nitrate or as sprays. Inclusion of the borax at the rate of 3 to 5 pounds per 100 gallons of fungicidal spray, *e. g.* Bordeaux, or 2 to 3 pounds per 100 gallons water was found to be an effective method of delayed application of borax, without causing any injury to the plants.

The Relation Between Boron and Calcium in the Growth of Garden Beets[1]

By O. A. Lorenz, *University of California, Davis, Calif.*

Abstract

The complete paper will be published as a part of a memoir of the Cornell Agricultural Experiment Station.

A FACTORIAL experiment using nutrient solutions containing various levels of B and Ca was conducted to determine the possible relations between B and Ca. Calcium nitrate was applied to nutrient solutions at rates to supply 10, 40, 160, and 640 parts per million Ca, while H_3BO_3 was added so as to supply 0.01, 0.05, and 0.10 parts per million B. Each of the 12 treatments was replicated four times.

There was a significant interaction of the effects of B and Ca on growth. Growth was increased above that produced in solutions receiving the minimum amounts of B and Ca by increasing the concentration of B without increasing the concentration of Ca, or by increasing the concentration of Ca without increasing the concentration of B. Increments of B were more efficient in increasing growth at the lower levels of Ca than at the higher levels of Ca, suggesting that B may aid the plant in the utilization of Ca.

When associated with increased growth, increasing the concentration of B in the nutrient solution resulted in increased absorption of Ca. Increasing the concentration of B did not result in greater Ca content per unit of dry weight of plants, regardless of the concentration of Ca in the solution. The amount of Ca absorbed by plants, as determined by the percentage composition of the plants or by loss from the nutrient solution, was increased as the concentration of Ca in the solution was increased, irrespective of the level of B.

The data indicate that B is more closely associated with the utilization than with the absorption of Ca.

[1]Paper No. 235 of the Department of Vegetable Crops, Cornell University, Ithaca, New York.

Studies in the Minor Element Nutrition of Vegetable Crop Plants II. The Interrelation of Potash, Boron and Magnesium upon the Flavor and Sugar Content of Melons[1]

By W. C. Jacob and R. H. White-Stevens, *Cornell University, Ithaca, N. Y.*

ONE of the most distinctive phases of boron nutrition of crop plants which has developed during the past two or three years is the interrelationship of this physiogenic disease with other nutritional factors. Although it has been known for some years that lime applications frequently amplify boron deficiency on soils low in that element, Minarek and Shive (3) have recently presented evidence to show that the level of boron in the plant's nutrition may control the absorption of calcium. This suggests the interesting possibility that the characteristic symptoms of boron deficiency may be actually calcium deficiency symptoms induced by the interruption in calcium absorption by lack of adequate boron.

Powers and Bouquet (4) and Purvis and Hanna (5) have presented preliminary evidence suggestive of the relation of potash nutrition to boron deficiency.

Knoblauch and Odland (2) have reported significant incidence of magnesium deficiency as the result of high potash fertilization on certain long time fertility plots at the Rhode Island Station.

Recently Purvis (6) in a general review of current advances in the field of boron nutrition, draws attention to the effect of related nutrient elements on the incidence of boron deficiency.

On Long Island soils boron deficiency is a major problem in vegetable crop production. Previous work, White-Stevens and Wessels (10), has indicated that nitrogen, phosphorus and potash levels in the fertilizer program are significantly related to the degree of boron deficiency which may occur under field conditions with certain susceptible vegetable crops. Further substantiation of these relations was obtained by greenhouse experiments with rutabagas. In general it was found that increased potash amplified boron deficiency both as to external symptoms and chemical composition.

This paper is concerned with a further consideration of this relationship of potash and boron, together with the introduction of magnesium to the complex, in their effect on the quality of muskmelons.

Materials and Methods

The experiment was conducted on a Dukes Sand at Selden, New York. The treatments consisted of all the combinations of the levels of the three factors listed in Table I, and these were arranged in each of four blocks in the field.

The variety of muskmelon used was Delicious from Harris. The soil reaction at time of planting was pH 5.8 to pH 6.0. The fertilizers were

[1]Paper No. 222, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

TABLE I—LEVELS OF FACTORS STUDIED IN EXPERIMENT TO DETERMINE INTERRELATION OF POTASH, BORON, AND MAGNESIUM ON THE FLAVOR AND SUGAR CONTENT OF MELONS

Potash		Magnesium		Boron
High, 150 pounds K_2O per acre	×	High, 60 pounds Mg O per acre	×	High, 15 pounds Borax per acre
Low, 75 pounds K_2O per acre		Low, nil Mg O per acre		Low, nil Borax per acre

applied broadcast by hand and disced into the surface 2 inches of soil. The plants were started in hot beds and set out on May 20th at a spacing of 6 by 6 feet giving 18 plants per plot.

Because of necessary limitations no yield data could be taken but observations as to quality were made. At about the time of peak harvest two ripe fruits — at full slip — were selected from each of the four replicates of each treatment and taken to the laboratory. The eight fruits from each treatment were considered as a composite sample and each fruit was quartered by longitudinal cuts, Scott (8), the various quarters being treated as outlined in Table II. One quarter was graded for flavor by the index method by two observers. A grade of 1 designated very flat and 9 designated excellent flavor. Various graduations were used between these limits. Another quarter was used to determine hexose and sucrose sugars as per cent of dry weight by alcohol extraction from the diced flesh. The flesh of the other two quarters was squeezed through cheesecloth and the juice thus extracted was analyzed for total dispersed solids after two methods of filtering and for hexose and sucrose sugars as grams in 100 cubic centimeters of juice. In all cases the sugars were determined by use of the Shaffer and Somogi (7) copper-iodine reagents, using a technique previously described by White-Stevens (9).

The observations are presented as the differences between the means of the levels of the various factors and their interactions, following the notation suggested by Yates (11). Since no field replications were maintained individually, statistical reduction of the data is impossible and the following discussion is merely to point out some interesting observations.

The correlations computed for expressing the relationship between the various methods of chemical analysis were calculated by the "r" test (1).

TABLE II—DISPOSITION OF EACH MELON WITH REGARD TO PORTIONS USED FOR EACH METHOD OF ANALYSIS

½ melon—Juice expressed through cheesecloth—		Filtered through Whatman No. 1 +talc.	Total dispersed solids as grams/ 100 cubic centimeters
			Hexose and sucrose as grams/ 100 cubic centimeters
		Filtered through Whatman No. 1	Total dispersed solids as grams/ 100 cubic centimeters
½ melon—	¼ melon	Flesh diced	2–100 grams fresh weight for dry weight determination
			100 grams fresh weight for alcohol extract—hexose and sucrose as per cent dry weight
	¼ melon		flavor index (1–9) two observers averaged

TABLE III—EFFECTS OF POTASSIUM, MAGNESIUM AND BORON ON THE FLAVOR INDEX AND TOTAL DISPERSED SOLIDS IN THE JUICE OF MELONS

Effect	Flavor Index	Total Dispersed Solids (G / 100 Cc)	
		Whatman No. 1	Whatman No. 1 + talc
Mean	5.75	5.81	3.29
K	−1.00	−0.44	−0.94
Mg	1.00	0.36	0.76
K Mg	0.50	−0.05	0.57
B	−0.50	−0.27	0.27
KB	0.00	−0.69	0.09
Mg B	−1.00	−0.32	−0.41
K Mg B	−0.50	−0.19	−0.58

RESULTS

Table III gives the main effects of the various factors, potash (K), magnesium (Mg), and boron (B), and their interactions as they influenced the flavor index and total dispersed solids per unit volume of the juice. It is of particular interest to note that in all cases potash showed a distinct negative effect, magnesium a positive one while boron was negative in two cases and positive in one.

Considering the nature of these effects for the flavor index test it can be seen that potash has as great a negative effect as magnesium does a positive one and the effect of boron though small is definitely negative. The relative efficacy of these elements in influencing flavor was therefore: Mg = K > B.

The first order interactions were in partial agreement only. The K Mg effect was distinctly positive in two methods and practically nil in the other. The K B effect was definitely negative in one method, very slightly positive in the other and zero in the flavor index test. The Mg B effect was negative in all of these methods.

The flavor index test gives the following indications from the first order interactions:

Magnesium was more effective when potash was high than when potash was low, pointing to a marked reduction of the deleterious potash effect by magnesium. Boron inhibited the beneficial effect of magnesium but had no influence on the potash effect.

The second order interaction was negative in all cases though small in one and for the flavor index test shows that boron effectively neutralized the inhibiting influence that magnesium had on the deleterious potash effect.

Table IV lists the main effects and interactions of the three elements as they influenced the carbohydrate composition of the expressed juice. Potash had a negative effect on the total soluble carbohydrate content caused by its large negative influence on the sucrose content. Magnesium had a positive effect in all forms and the boron effect was very slightly negative on the total but quite large and negative for the sucrose. Hexose was more prevalent than sucrose.

Considering the first order interactions it is seen that magnesium reduced the deleterious potash effect on the hexose and amplified it on the sucrose. Magnesium neutralized the beneficial boron effect on the hexose and reduced the deleterious effect of the boron. Boron reduced

TABLE IV—EFFECTS OF POTASSIUM, MAGNESIUM, AND BORON ON SUGAR CONTENT OF EXPRESSED JUICE OF MELONS

Effect	(Grams Per 100 Cc Juice)		Total*
	Hexose	Sucrose*	
Mean	2.39	0.75	3.14
K	0.03	-0.52	-0.49
Mg	0.32	0.03	0.35
K Mg	0.27	-0.40	-0.13
B	0.07	-0.14	-0.07
KB	-0.23	0.02	-0.21
Mg B	-0.08	0.08	0.00
K Mg B	0.03	-0.04	-0.01

*Expressed as hexose.

the beneficial potash effect on the hexose and amplified the deleterious effect on the sucrose. Potash and boron reduced the efficacy of one another on the total sugar content, the best combination being low potash and high boron.

Table V presents the main effects and interactions of the factors as they affect the soluble carbohydrate composition expressed as per cent of the dry weight. Potash reduced the total carbohydrate composition and also both hexose and sucrose but its effect was greater on sucrose than hexose. Boron had a negative effect on the total carbohydrate content coming from the large reducing effect on the hexose. Magnesium had very little influence on the carbohydrates as expressed in this manner.

The K Mg interaction was very small on the hexose and sucrose and total. Boron reduced the deleterious potash effect on the hexose content but amplified it markedly on the sucrose giving the negative interaction effect found in the total carbohydrates. Boron reversed the deleterious effect of magnesium on the hexose content and reversed the beneficial magnesium effect on the sucrose.

The fact that somewhat variable results may be obtained by estimating the quality of muskmelons by various methods has already been indicated, but in general the main effects are consistent both as to sign and relative dimension.

Table VI shows a summary of correlation coefficients between the treatment means obtained by the various methods. All the methods seem to be highly correlated but the sucrose expressed as grams per

TABLE V—EFFECTS OF POTASSIUM, MAGNESIUM AND BORON ON SUGAR CONTENT OF FLESH OF MELONS

	Per Cent of Dry Weight		
Effect	Hexose	Sucrose*	Total*
Mean	52.03	11.61	63.64
K	-2.07	-7.21	-9.28
Mg	0.75	-0.21	0.54
K Mg	-0.05	-0.40	-0.45
B	-6.05	2.67	-3.38
KB	1.51	-4.58	-3.07
Mg B	1.90	-3.35	-1.45
K Mg B	0.18	1.18	1.36

*Expressed as hexose.

TABLE VI—CORRELATION COEFFICIENTS BETWEEN VARIOUS METHODS OF ESTIMATING QUALITY AND CARBOHYDRATE CONTENT IN MELONS

No	Method Description	2	3	4	5	6	7	8	9
1	Flavor Index	0.9922‡	0.9925‡	0.9889‡	0.9166†	0.9774‡	0.9871‡	0.9388‡	0.9908‡
2	Dispersed solids filtered through Whatman No. 1	——	0.9798‡	0.9954‡	0.9206†	0.9871‡	0.9950‡	0.9420‡	0.9979‡
3	Dispersed solids filtered through Whatman No. 1 +talc	——	——	0.9803‡	0.9075†	0.9712‡	0.9717‡	0.9427‡	0.9790‡
4	Hexose gms per 100 cc filtered juice	——	——	——	0.8875†	0.9796‡	0.9910‡	0.9279‡	0.9919‡
5	Sucrose gms per 100 cc filtered juice	——	——	——	——	0.9524‡	0.9206†	0.9164†	0.9322‡
6	Total sugar gms per 100 cc filtered juice	——	——	——	——	——	0.9920‡	0.9466‡	0.9993‡
7	Hexose as per cent dry weight	——	——	——	——	——	——	0.9160†	0.9969‡
8	Sucrose as per cent dry weight	——	——	——	——	——	——	——	0.9448‡
9	Total sugars as per cent dry weight	——	——	——	——	——	——	——	——

*Required at 5 per cent point = 0.7067.
†Required at 1 per cent point = 0.8343.
‡Required at 0.1 per cent point = 0.9249.

100 cubic centimeters of filtered juice seemed to be less associated with the other methods. However, the odds are high even in this case.

DISCUSSION

The most consistent effect found to be present by each of the five methods tested is the distinctly negative potash effect, and furthermore in all interactions involving potash this reducing effect occurred, the interaction invariably arising from differential influence of the associated factor upon the deleterious potash effect. In its effect upon the distribution of soluble carbohydrate form, potash appeared to have a greater reduction upon the sucrose than upon the hexose.

Magnesium showed a consistent stimulating effect upon flavor, total dispersed solids and in sugar concentration. In its interactions this beneficial effect persisted, although it tended to be more positive upon the hexose than the sucrose. When magnesium interacted with boron a negative effect was produced which indicated that each element inhibited the beneficial effects of the other.

Boron showed in general a reducing effect, but tended to increase sucrose at the expense of the hexose, and also showed a distinct neutralizing effect upon the deleterious potash effect. However boron did not amplify the beneficial magnesium effect but by two methods showed no interaction and by the others a slight negative influence.

No fundamental explanation as to the persistent K and B and K B effects can be made as yet, but its recurrence in several different crops involving boron deficiency merits further consideration.

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Injuries Produced by Saline and Alkaline Waters on Greenhouse Plants and the Alleviation of Alkaline Injury by Neutralization

By R. H. HAGEMAN and E. L. HARTMAN, *Oklahoma A. & M. College, Stillwater, Okla.*[1]

IN PREVIOUS experiments upon the toxicity of saline and alkaline waters (2, 3) it was noted that sodium bicarbonate solutions were more toxic to most plants than equivalent concentrations of the other salts. The greater toxicity of the sodium bicarbonate was probably due to the injurious effects of the sodium and bicarbonate ions, the elevated pH values and the fact that certain elements are not readily available to the plants because of their lower solubility under alkaline conditions.

Alkaline waters containing large proportions of bicarbonate ion are prevalent in many western and southwestern states and constitute a major problem to agricultural production. Although some procedures and apparatus, applicable for greenhouses, have been developed for the continuous neutralization of large quantities of water, many difficulties are still presented.

The purpose of this experiment was to determine the degree to which sodium bicarbonate injury to tomato plants was alleviated by neutralizing the alkali with sulphuric acid, nitric acid, phosphoric acid, sulphur and superphosphate, respectively.

MATERIALS AND METHODS

Marglobe variety tomatoes were selected as the experimental plant because of the background of experience and data acquired in previous work. A sand culture method, using fine quartz sand and a nutrient solution described in a previous publication (3) was used to grow the plants. Uniform plants 4 inches in height were transplanted into 6-inch clay pots; these pots were arranged into groups of five and the groups into series. The grouping and the treatment of each group of five plants are shown in Table I.

TABLE I—EXPERIMENTAL TREATMENT OF TOMATO PLANTS AND PARTS PER MILLION OF $NaHCO_3$ ADDED TO NUTRIENT SOLUTION

Treatment	Parts per Million of $NaHCO_3$					
$NaHCO_3$ unneutralized	500	1000	1500	2000	2500	3000
$NaHCO_3$ + H_2SO_4 to neutrality	500	1000	1500	2000	2500	3000
$NaHCO_3$ + HNO_3 to neutrality	500	1000	1500	2000	2500	3000
$NaHCO_3$ + H_3PO_4 to neutrality	500	1000	1500	2000	2500	3000
$NaHCO_3$ + Superphosphate, 5 g./gallon	500	1000	1500	2000	2500	3000
$NaHCO_3$ + Sulphur, 5 g./gallon	—	1000	—	2000	—	3000

Plus five control groups.

In all cases the sodium bicarbonate or the sodium bicarbonate plus the calculated quantity of neutralizing agent was added to the nutrient solution and the mixture stored in a 4-gallon crockery jar. The pH of

[1]Permission for publication given by the Director of Oklahoma Experiment Station.

all solutions were adjusted to a pH value of 5.6 to 6.0, with the exception of sulphur and superphosphate treatments.

All solutions were vigorously stirred before the daily application to the plants. Applications of solutions were varied in order to provide for the water requirements of all plants. The plants treated with the increasing higher concentrations of unneutralized or neutralized alkali required less water. The sand in each pot was leached once a week with cistern water to prevent excessive accumulation of salts. The plants were immediately rewatered with their respective solutions after each leaching. Records were kept of the quantity of solution used and weekly observations were made upon the apparent condition of the plants. The experiment was terminated at the end of nine weeks because the varying degrees of toxicity were well defined at that time. The plants were harvested by clipping off at the surface of the ground. Each group was weighed to determine the green weight, then dried, first in a steam-heated dehydrator, then in an oven at 105 degrees C for 24 hours, and reweighed to determine the dry weight. Each sample was ground through a 0.5 millimeter screen in a Wiley mill and later analyzed for ash, calcium, magnesium and sodium, according to the methods of A.O.A.C. (1).

The colored photographs taken constitute the best general record of the plant growth and coloration, but for economic reasons they are not reproducible here, and are thus replaced by the observations recorded.

Results

The high toxicity characteristic of the sodium bicarbonate was illustrated by dead lower leaves, progressive chlorotic discolorations, and stunted growth of the plants. There was an apparent, sharp rise in injury to the plants treated with 1500 and 2000 parts per million of sodium bicarbonate.

The series neutralized with phosphoric acid, the acid commonly recommended for neutralizing alkaline waters, demonstrated an apparent decrease in the injury and an improved appearance and color of the plants; however, a high degree of injury was still apparent by the sharply stunted plant growth treated with 1500 and 2000 parts per million concentrations of the neutralized alkali.

The series of plants, in which nitric acid was the neutralizing agent, showed a lessened toxicity and improved plant appearance both in size and color.

Plants treated with sodium bicarbonate neutralized with sulphuric acid, gave by far the best results of the treatments tried. The plants at the highest concentration, 3000 parts per million of sodium bicarbonate, which were neutralized with this acid appear equal in color and nearly equal in size, to the control plants.

Two experiments were tried in which substances other than acids were used as the neutralizing media. One, superphosphate, was added on the theory that there would be some neutralization from the residual acidity, and that the additional phosphorus might increase the metabolism of protoplasm, thereby increasing the amount of colloidal adsorptive material in the plant tissue. There was very slight, if any, improve-

ment in the size and appearance of this series compared to the plants treated with unneutralized sodium bicarbonate.

Sulphur was added as a neutralizing agent, as in the presence of air it is slowly oxidized to sulphuric acid, which process it was thought might provide a gradual neutralization of the sodium bicarbonate. Careful observations indicated that the plants treated with higher concentrations of sodium bicarbonate and neutralized with sulphur had longer internodes, less dense foliage, smaller stocks and attained greater height. The dry weight of the plants treated with the higher concentrations of the alkali thus neutralized were less than the dry weight of the plants treated with the lower concentration.

The dry weight of all series have been determined and are illustrated graphically in Fig. 1. The dash line represents the unneutralized

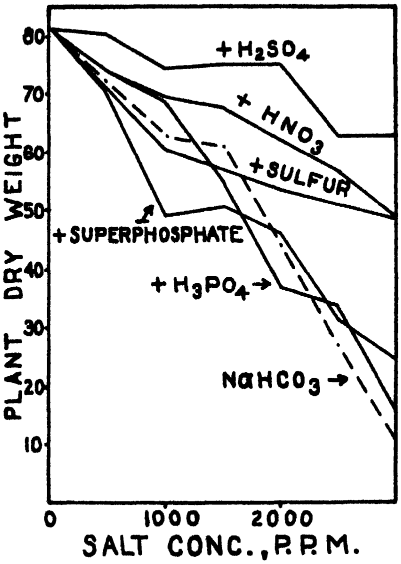

FIG. 1. Dry weight of tomato plants —$NaHCO_3$ neutralized as indicated.

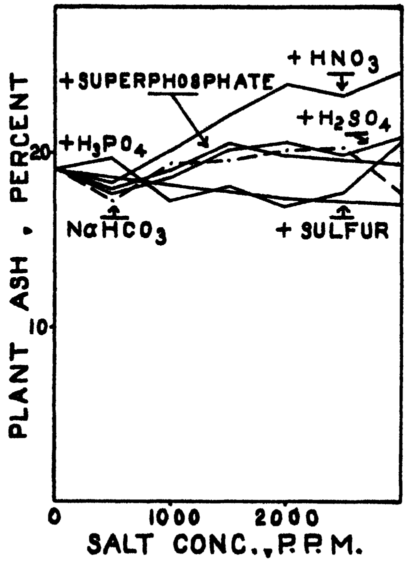

FIG. 2. Ash content of tomato plants —$NaHCO_3$ neutralized as indicated.

sodium bicarbonate series; solid lines represent equal concentrations of sodium bicarbonate neutralized as noted.

The growth of the plants in the series neutralized with sulphuric acid demonstrated that this was the most effective treatment. The growth of plants treated with the maximum concentration of alkali and neutralized with sulphuric acid was not reduced sufficiently to render production unprofitable.

The nitric acid treatment was less beneficial, but still proved valuable in the alleviation of alkaline injury. The sulphur treatment was of value in reducing the extreme toxicity of the higher concentrations, and the phosphoric acid and superphosphate treatments of no significant value.

Ash, calcium, magnesium and sodium were determined in an effort

to find if there was any correlation between analytical data and plant growth, and to ascertain the effect of the various treatments upon the assimilation of the various ions.

The ash content of the plants of each series are shown in Fig. 2. Although the neutralization of the sodium bicarbonate with sulphuric acid was the most effective in alleviation of injury to the plants, and superphosphate the least effective, these two series of plants had essentially the same ash content as the plants treated with the unneutralized sodium bicarbonate. The highest content of ash was in the plants treated with sodium bicarbonate and neutralized with nitric acid. The plants assimilated less minerals when sulphur and phosphoric acid was used for the neutralization.

The calcium content of each series of plants is shown in Fig. 3. The

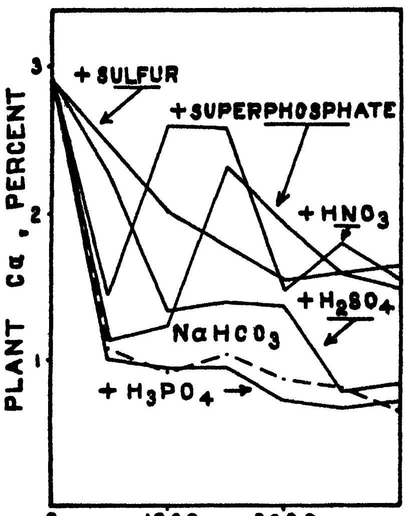

FIG. 3. Calcium content of tomato plants — $NaHCO_3$ neutralized as indicated.

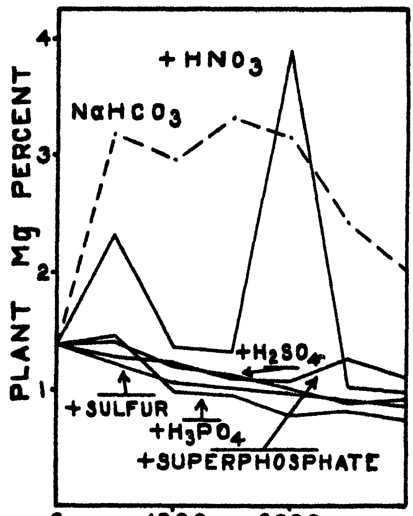

FIG. 4. Magnesium content of tomato plants — $NaHCO_3$ neutralized as indicated.

nitric acid treatment gave the highest absorption of calcium; sulphuric acid, a slight increase; and phosphoric acid no appreciable difference when compared to the unneutralized sodium bicarbonate series. The plants treated with superphosphate gave an appreciable increase in plant calcium. Sulphur treatment gave a greater increase in plant calcium than would be predicted from the sulphuric acid curve.

The curves in Fig. 4 show how the plants assimilated magnesium under the various treatments. The unneutralized sodium bicarbonate curve demonstrates abnormally high absorption, and the nitric acid curve an erratically high magnesium content. All other treatments lowered the magnesium content of the plants as indicated by the general trend of the curves in Fig. 4.

The sodium content of each series of plants is demonstrated by the

curves in Fig. 5. The sulphur treatment exhibited the greatest depression of sodium content in the plants. The sodium content was highest in the plants where nitric acid was used as the neutralizing agent being slightly higher than the unneutralized sodium bicarbonate series. Plants treated with the other neutralizing agents contained slightly less sodium than the unneutralized alkali series.

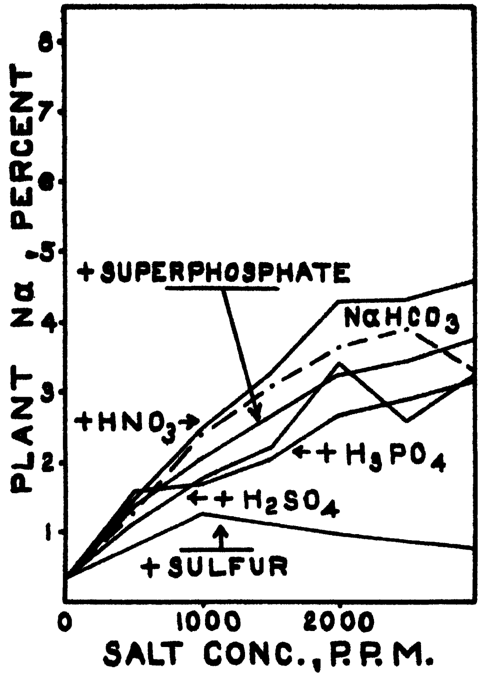

FIG. 5. Sodium content of tomato plants — $NaHCO_3$ neutralized as indicated.

The analysis of the analytical results does not permit any significant correlations with the plant growth data. It is interesting to note, however, that the plants treated with sodium bicarbonate neutralized with nitric acid had higher ash and mineral content, those treated with sulphuric acid neutralization an intermediate value, and those with phosphoric acid neutralization a lower value. These results could be predicted from the relative solubilities and dissociation constants of their respective salts.

It must be remembered that these plants were grown in a sand media and that their reactions would not necessarily be identical with plants grown in soil. This is indicated by the rather ineffective influence of sulphur as a neutralizing agent in the sand media, whereas Ahi and Powers (4) and many other writers have found sulphur to be quite effective in reclamation of alkali land. Sulphur addition to the sodium bicarbonate treatments did not alleviate alkali injury as measured by plant growth in the sand media. However, the decrease in the sodium content of the plant material with the increasing sodium bicarbonate additions indicates that sulphur may function in this manner as an important alleviating agent in alkali soils.

SUMMARY

A study was made to determine the degree to which sodium bicarbonate injury to tomato plants grown in sand cultures was alleviated by neutralizing the alkali with sulphuric acid, phosphoric acid, nitric acid, sulphur and superphosphate, respectively.

Using plant growth, measured by the dry weight of the plants and observed appearance as criteria, the following results were obtained:

In the unneutralized sodium bicarbonate series the plant injuries were accentuated as the concentrations were increased. Plants treated with solutions containing 1500 to 2000 parts per million of unneutralized alkali were reduced in dry weight to one-half that of the control plants.

The plants treated with solutions containing the highest concentration of sodium bicarbonate (3000 parts per million) when neutralized with sulphuric acid, were but slightly injured in growth and appearance. Under these conditions this treatment proved to be most effective from an economic standpoint.

When nitric acid was used as the neutralizing agent, there was some alleviation of the alkaline injury. Nitric acid, however, was not as effective as the sulphuric acid in the reduction of injury to the plants.

The sulphur treatment was of value in reducing the extreme toxicity of the higher concentrations. Superphosphate and phosphoric acid exhibited little or no activity in alleviation of sodium bicarbonate injury to the tomato plants.

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The Relation of Soil Moisture to the Time of Bloom of Calendulas, Larkspurs and Geraniums

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IT HAS long been a policy of commercial greenhouse men to "run plants dry", that is, withhold water in order to hasten their flowering. One of the best examples of this is the common practice of drying the soil of geranium plants to time their flowering and bring them into bloom for Memorial Day. The plants frequently wilt, but are not permitted to become sufficiently dry to lose their leaves. Experimental evidence does not show that this practice gives the anticipated results. Work with vegetables, Chroboczek (1), shows that the practice does result in a hardening of plants, as shown by an increase in tensile strength and in the ability of the plant to withstand adverse climatic conditions. Anatomically, this appears as thickened cell walls, compact cells, thicker cuticle, smaller leaves and an accumulation of storage materials.

In order to determine the merits of this practice, an experiment was set up at Cornell University to study the effects of different levels of soil moisture and of watering systems on the time of bloom of certain flowering greenhouse plants. Work done with auto irrigators is not considered in this paper.

THE MAINTENANCE OF WATER CONTENT

Gallon-size glazed crocks were used as plant containers in the experiments. Dry composted clay loam soil was placed in three piles and water added to produce a different soil moisture condition in each. Three samples of soil were then taken from each pile for the determination of moisture content. These were first oven dried and then exposed in air for 1 week. The average percentages of moisture on the air dry basis were 30.4, 24.7 and 15.0 per cent for the wet, moist, and dry soils respectively.

The moist soil had good moisture content for potting. It was sufficiently moist to mold when squeezed in the hand and yet would crumble readily. The dry sample would not mold when squeezed in the hand and the wet soil was sticky and would mold but not crumble, and when squeezed, it would ooze through the fingers.

All plants used in the experiment received four treatments of three plants each.

A. High soil moisture throughout the duration of the experiment so that the soil was relatively wet.
B. Medium or optimum soil moisture throughout the course of the experiment.
C. Medium soil moisture until buds appeared and then changed to low soil moisture for the remainder of the experiments.
D. Low soil moisture throughout the duration of the experiment so that the soil was relatively dry.

The crocks were weighed daily and sufficient water added to bring

the apparatus and plant up to its original weight. Each week one plant of each variety of comparable size was lifted from the soil, the roots carefully washed free of all soil particles, and the fresh (or green) weight determined. The fresh weight of this plant was then added to the combined original weight of the plant, soil and glazed crock to allow for the increase in weight due to the growth of the plants.

It was realized that if the water lost from the soil mass by evaporation and transpiration was replaced only at the top of the soil in the containers, eventually an uneven moisture distribution in the crocks would develop. In order to obtain a more satisfactory distribution, a number of 1-inch diameter glass tubes were inserted to different depths in the containers and a portion of the water was applied through them as well as to the surface soil. By this method a relatively uniform distribution of moisture was obtained as evidenced by examination of the soil mass at the completion of each part of the experiment. Capillary movement of water laterally through the soil further aided in distribution, Richards (3). Uniform and extensive root development was observed throughout the soil mass as it was taken from each container, also indicative that the moisture was well distributed.

The water was undoubtedly less uniformly distributed in the containers of low soil moisture, certain portions of soil being near to field capacity at times and others more dry. However, whether the net result of the small amounts of water received was in limiting the feeding area of the plant roots or a direct physiological effect of dessication, the experiment still is representative of the commercial treatments given flowering greenhouse plants to hasten their flowering.

Calendulas

Calendula officinalis plants of the variety "Ball Gold" were grown from seed. The seedlings were shifted to 2-inch pots and when they attained the proper size for benching were selected for uniformity and one placed in each of the 1-gallon size glazed crocks.

The results (Table I) indicate that low soil moisture delayed flowering rather than hastened it. The soils with medium amounts of moisture served as a control or check in this experiment. The soil moisture was maintained at what was considered optimum and the plants appeared normal in regard to size and type of growth. When the first buds appeared, part of these plants were allowed to become dry and the soil moisture content permitted to become low. These plants flowered, on an average, 7 days later than the check plants.

Plants grown continuously in dry soil were delayed even longer in flowering, which agrees with the findings of Kibbe (2). A slight delay was also noted in the flowering of the plants grown in wet soil.

Larkspurs

Delphinium ajacis plants, common larkspur, of the variety "Branching White Spire" were used. The plants were grown from seed, transplanted to 2-inch pots and when ready for benching were selected for uniformity and one placed in each of the 1-gallon size glazed crocks containing soils at different moisture levels.

TABLE I—THE RELATION OF SOIL MOISTURE CONDITIONS TO THE TIME OF BLOOM OF CALENDULAS, LARKSPURS AND GERANIUMS

Treatment	Calendulas		Larkspurs		Geraniums
	Average Time of First Bloom (Days)	Delay of First Bloom Over Checks (Days)	Average Time of First Bloom (Days)	Delay of First Bloom Over Checks (Days)	Average Time of First Bloom (Days)
A—Wet	134	5	187.5	10.5	31.5
B—Medium	129	0	198.0	0.0	—
C—Medium to dry	136	7	212.0	14.0	—
D—Dry	138	9	216.0	18.0	40.1*

*Indicates that only two-thirds of the plants bloomed.

In this experiment (Table I) as with calendulas, the plants growing under conditions of medium or optimum soil moisture were used as controls. The plants changed from a medium to a dry soil moisture content following the setting of flower buds were delayed in flowering an average of 14 days. The plants grown in dry soil continuously were delayed an average of 18 days. The plants grown in wet soils, however, flowered 10.5 days earlier than the control plants.

GERANIUMS

Rooted cuttings of *Pelargonium hortorium,* the common house geranium were purchased in November and potted in 3-inch pots. On March 1, they were moved to 4-inch pots. Thirty plants were selected for uniformity on April 7 and placed in the experiment.

This experiment was simplified to two treatments. In the first treatment, one-half of the plants were maintained at low soil moisture content. In the second treatment, one-half of the plants were kept at a high soil moisture content.

The plants had been blooming for some time when the experiment began. All blossoms and buds were removed and data taken on the time interval for the appearance of more blossoms.

The plants receiving the dry soil treatment bloomed much later than the plants that were watered frequently, (Table I). At the time the experiment was concluded, only two-thirds of the dry soil plants had bloomed in an average time of 40 days, while all the wet soil plants had bloomed in an average of 31.5 days.

CONCLUSION

With the Calendula, Larkspur and Geranium plants, low soil moisture conditions did not result in a more rapid flowering, but actually resulted in delayed flowering.

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Some Aspects of the Nutrition of the Gardenia

By D. C. Kiplinger and Paul H. Bender, *Ohio Agricultural Experiment Station, Wooster, Ohio*

NUTRITIONAL factors affecting the growth and production of gardenias have been investigated at the Ohio Station by growing the plants in gravel culture. Plants of the Belmont type and Veitchii species were benched February 16, 1939, in gravel culture experimental plots described by Kiplinger and Laurie (2) with C Haydite, coarse cinders, silica gravel, and calcareous gravel as media. The solutions used were the Ohio WP (3) and New Jersey rose solution (1). Production records were taken until May 28, 1940.

pH Level

Determination of the optimum pH level to maintain in the Ohio WP was carried out in C Haydite. Commercial sulfuric acid and sodium, potassium, and ammonium hydroxides were used to maintain pH levels, which were adjusted every other day. Results are shown in Table I.

TABLE I—Optimum pH for Gardenias in Gravel Culture

pH	Flowers Per Plant	
	Belmont Type	Veitchii
7.0–7.5	35.5	33.9
6.0–6.5	31.0	28.7
5.0–5.5	23.5	23.2
4.0–4.5	26.3	16.2

Although the plants at the higher pH levels exhibited chlorosis, production was higher and growth was superior. The use of ferrous sulfate to overcome chlorosis at the higher pH levels resulted in a drop in pH and applications were limited. The use of ammonium hydroxide appeared to decrease the time required for flowers to open.

Media Tests

Difficulty in obtaining suitable media for various crops has been experienced by commercial florists. The two varieties were benched in plots of C Haydite, coarse cinders, silica gravel and calcareous gravel, using the Ohio WP solution. Results in Table II show that there is some variation in production but that calcareous gravel, be-

TABLE II—The Effect of Various Media on Gardenia Production

Media	Flowers Per Plant	
	Belmont Type	Veitchii
Coarse cinders	29.0	21.5
Silica gravel	24.5	28.3
C Haydite	23.5	23.2
Calcareous gravel	16.0	6.5

TABLE III—PRODUCTION FROM OHIO AND NEW JERSEY SOLUTIONS

Solution	Flowers Per Plant	
	Belmont Type	Veitchii
Ohio WP	24.3	28.3
New Jersey Rose	15.6	12.6

cause of its extreme alkalinity, is undesirable for gardenias. Adjustment of the pH of the solutions in the other three media with commercial sulfuric acid and sodium, potassium, and ammonium hydroxides is economically feasible, but it is not true of calcareous gravel.

SOLUTION TESTS

A New Jersey rose solution modified for use on gardenias (1) and the Ohio WP (3) solution each at a pH of 5.0 to 5.5 were applied to gardenias in silica gravel. Both solutions were maintained as suggester by each station. The results in Table III show that the Ohio WP solution produced more flowers per plant. The high nitrate level of the New Jersey solution was not conducive to good root action and was caused by frequent additions of ammonium sulfate which also lowered the pH. The lower pH ranges caused iron to become toxic, resulting in leaf drop, bud drop, and bud splitting.

IRON SOURCES

Chlorosis of gardenias in gravel culture is often caused by a lack of iron in the solution. The following materials were applied weekly to dark green Gardenia veitchii plants: 40 parts per million of iron from ferric citrate ($(FeC_6H_5)_7.3H_2O$), 40 parts per million of iron from ferric tartrate ($Fe_2(C_4H_4O_6)_3.H_2O$), 40 parts per million of iron from ferrous sulfate ($FeSO_4.7H_2O$), 20 parts per million of iron from ferric pyrophosphate ($Fe_4(P_2O_7)_3.9H_2O$). Ten parts per million of iron from iron humate were applied monthly to an additional plot. With the exception of ferric citrate, all materials tested were satisfactory as iron sources. Ferrous sulfate caused a drop in pH and some precipitation of phosphorus; ferric citrate a slight rise in pH; while all other materials did not materially affect the pH or nutrient levels. Ferrous sulfate is recommended for use in gravel culture as it is available in a commercial grade known as copperas.

SUMMARY OF RESULTS

Highest production of gardenias was obtained at pH 7.0 to 7.5 in a WP solution though the plants were often chlorotic. Either C Haydite, coarse cinders, or silica gravel were suitable as media. Calcareous gravel is alkaline and resulted in stunted plants producing few flowers. The Ohio WP solution was superior to the New Jersey rose solution, probably because of a better balance of nutrients. Ferric tartrate, ferric phosphate, ferric pyrophosphate, iron humate, and ferrous sulfate were satisfactory sources of iron for gardenias. Ferrous sulfate is recommended as it is available commercially and is economical.

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Nutritional Studies of the Greenhouse Rose

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Abstract

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ROSES in gravel culture may be grown most easily using nitrate nitrogen from potassium nitrate, sodium nitrate or calcium nitrate, with supplements of ammonia nitrogen, during winter months. If pH levels are carefully maintained, ammonia nitrogen may be used safely as the sole source of nitrogen.

Allowing the pH of ammonium nitrate and ammonium sulfate solutions to drop caused defoliation and induction of semi-dormancy. No root injury was observed.

Roses of stem lengths between 12 and 21 inches were produced from flowering or blind wood in a shorter time than the lower or higher grades. Flowers from blind wood required a slightly longer time to mature than flowers from flowering wood.

Effects of Temperature on Growth and Flower Production of Gardenias[1]

By O. W. DAVIDSON, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*[2]

THE results of root temperature investigations conducted by Jones (1) on gardenias have prompted two questions concerning their application in practice: (a) What are the relative influences of root and air temperatures on the growth of gardenias? (b) Does light intensity influence the effects of root temperatures on these plants? While the studies reported herein dealt primarily with the first query, they furnish information concerning the second also.

EXPERIMENTS WITH GARDENIA VEITCHII

A group of uniform *Gardenia veitchii* plants, propagated in December 1937 and grown in sand cultures, was selected on October 25, 1938 and transplanted from 8-inch clay pots to 10-inch glazed crocks in constant temperature tanks. The latter were of the Chicago type described by Link (2). Eight plants, each of which comprised approximately 200 inches of linear twig growth, were placed in a tank, and were arranged in such a manner that every plant received an abundance of light. Throughout the experiment the plants were grown in sand cultures supplied with a complete nutrient solution daily.

Four different root temperatures, 58, 66, 74, and 82 degrees F, were used and each was maintained at approximately ± 1.5 degrees F of the desired value by means of thermostatic controls. The tanks were arranged in three separate greenhouse compartments, each of which was maintained manually at a different range of air or "house" temperature as indicated in Table I.

Soon after the start of the investigation the plants became infected by a bacterial leaf spot, the control of which warranted the use of an abnormally low humidity for gardenias throughout the experiment. Under these growing conditions bud drop was especially high with plants in the warm house, and was high with plants in the 74 and 82 degrees root treatments in the intermediate house temperature.

Plant Responses:—The results of temperature studies on *Gardenia veitchii* are summarized in Tables I and II. They show that both root and air temperatures have marked effects upon the vegetative growth of these plants. Thus it may be seen that the length of internodes of stems, as well as the amount of linear twig growth and the size of foliage, was considerably reduced either by low root temperature treatments in the intermediate, or "normal", air temperature, or by low air temperatures despite warm (74 degrees) root temperatures.

In general, the percentage of dry matter in young stems increased with decreases in either air or root temperatures. A notable exception

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Division of Horticulture.

[2]Assistance for this investigation was furnished by the personnel of Works Projects Administration Official Project No. 1778–12.

TABLE I—EFFECTS OF VARIOUS ROOT AND AIR TEMPERATURES ON THE GROWTH AND CONDITION OF *Gardenia veitchii*

Tank No.	Root Temp.	Greenhouse Temperature (Degrees F)		Comparison of Stem Tips Comprising Last 5 Internodes		Increase in Total Linear Growth Nov 2, '38 to Mar 2, '39 (Per Cent)	Foliage	
		Day	Night	Length (Inches)	Dry Matter (Per Cent)		Blade Size of Largest Mature Leaves on New Growth (Inches)	Color
1	66	75–78	68	4.1	32.3	64.2	2.8 ×1.4	Good
2	74	75–78	68	4.5	33.4	65.7	2.9 ×1.5	Good
3	82	70–74	62	4.3	30.9	72.6	2.9 ×1.5	Good
4	74	70–74	62	4.1	31.2	35.9	2.7 ×1.5	Good
5	66	70–74	62	3.3	32.1	36.2	2.7 ×1.4	Slightly chlorotic
6	58	70–74	62	3.2	35.5	4.9	2.2 ×1.1	Badly chlorotic
7	74	65–68	58	3.5	33.3	38.2	2.5 ×1.2	Slightly chlorotic
8	66	65–68	58	3.4	34.4	29.4	2.4 ×1.2	Considerably chlorotic

to this occurred, however, in plants grown in tanks 1 and 2 in the warm house. Plants in these treatments grew very rapidly and produced relatively long internodes, but their young stems were not so succulent as were those produced in corresponding root temperatures in the intermediate house. It seems likely that this was due to the comparatively low atmospheric humidity that was maintained, since the combination of high temperatures and low humidity tends to form woodiness in plants.

It may be observed from the data in Table I that, although the plants in the 66 degrees F root treatment in the warm house possessed good foliage color, those maintained at the same root temperature in the intermediate and cool houses produced chlorotic leaves. Similarly, the data show that a root temperature of 74 degrees F was conducive to good foliage color in the intermediate, or "normal", air temperature, but it did not prevent the development of chlorotic leaves on plants grown in the cool house.

The yield data shown in Table II indicate that, although the plants grown under medium or high root temperatures in intermediate or warm air temperatures produced the greatest amounts of growth and

TABLE II—EFFECTS OF VARIOUS ROOT AND AIR TEMPERATURES ON YIELDS FROM *Gardenia veitchii*

Tank No.	Buds Present Per Plant Mar 9, '39	Yields Per Plant Nov 1, '38 to Apr 12, '39		Quality of Blooms
		Blooms Cut	Blooms Unsalable	
1	55	14.7	2.6	Good
2	58	9.0	1.7	Good, large, long stems
3	57	16.6	3.6	Good, large, long stems
4	53	19.1	5.5	Good
5	45	22.8	6.8	Fair, short stems
6	39	13.0	7.4	Poor, stems too short
7	46	21.1	6.7	Fair, short stems
8	51	26.3	8.9	Fair, short stems

the greatest numbers of buds, they also experienced the greatest amounts of bud drop. On the other hand, these plants produced by far the finest blooms obtained from the experiment. They were large and possessed long to very long stems, with large, dark green, glossy foliage. In contrast to these blooms, those produced by plants in tanks 5, 6, 7 and 8 were only fair to small in size, and possessed short stems and chlorotic foliage. In the latter treatments the root or air temperatures, or both, were too low for this species. The flowers produced by plants in tank 6 were particularly poor, while those from plants in tank 8 were better than the former but possessed poor foliage and very short stems.

Conclusions:—The results of this investigation indicate that, provided root temperatures are well above 58 degrees F, a warm air temperature tends to offset the inhibiting effects of a low root temperature. Likewise, low air temperatures tend to offset the growth-stimulating effects of high root temperatures.

These interrelationships of root and air temperatures have been observed to operate in commercial gardenia production. In houses not provided with "bottom heat", it has been possible to control chlorosis by raising the air temperature. This is in agreement with the observations of McLellan (3), who finds that where proper air temperatures are maintained in houses equipped with raised benches, soil temperatures are ideal for gardenias.

Experiments with Gardenia Grandiflora

Because of the bacterial leaf spot that infected the gardenias of the 1938–39 experiment and the effects of the low humidity, necessitated by its control, on the growth of the plants, a part of that work was repeated in the winter of 1939–40 with the variety Belmont, of the grandiflora species. The plants used were propagated in early January of 1939 and grown in sand culture until transplanted to the constant temperature tanks on November 13. New covers were made for the tanks in order that six plants of this large species might receive the space previously devoted to eight.

The plants comprised about 350 inches of linear twig growth at that time. They were maintained in sand cultures and received a complete nutrient solution at pH 5.5 daily. Four constant temperature tanks, one maintained at each of the following temperatures: 58, 66, 74, and 82 degrees F, were used in the same greenhouses and subjected to the same atmospheric conditions, *i.e.* approximately 72 to 75 degrees F in the day and 66 to 68 degrees F at night, with high relative humidity at all times. The plants were well spaced and received an abundance of light. They grew well in their respective treatments and, except for one plant that was replaced early in the experiment because of stem cankers, they were free from disease.

Plant Responses:—The results of this experiment are summarized in Table III. They show conclusively that root temperatures as low as 58 degrees F have drastic effects upon the metabolism of the plants, more drastic with Belmont than with veitchii. Plants in both the 58 degrees and the 66 degrees treatments experienced heavy bud drop,

TABLE III—RESPONSE OF BELMONT GARDENIA PLANTS GROWN AT "NORMAL" AIR TEMPERATURES BUT DIFFERENT ROOT TEMPERATURES

Root Temp. (Degrees F)	Average Blooms Per Plant*	Average Buds Dropped Per Plant*	Condition of Foliage
58	0.7	13.8	Small and chlorotic
66	16.0	13.0	Normal to slightly chlorotic
74	21.3	10.0	Normal
82	18.0	12.2	Normal

*For the period December 15, 1939 to April 1, 1940.

and developed chlorotic foliage. In the 58 degrees treatment, however, the foliage was much smaller and much more chlorotic than in the 66 degrees treatment. It is significant to note that during February of 1940 the chlorosis disappeared from the foliage of plants in the 66 degrees root temperature. This response to increased light intensity is in agreement with the observations of McLellan (3). Moreover, with the increase in light intensity and length of day during February and March, plants in the 66 degrees treatment showed the greatest increase in bloom production, showing that light must also be considered in temperature and chlorosis relationships.

Plants in the 74 degrees and 82 degrees root temperatures grew rapidly and set an abundance of buds. The buds developed quickly and the blooms produced were of fine quality, with long stems and large, dark green leaves. In the 82 degrees root treatments the plants produced slightly longer internodes than did those in the 74 degrees treatments. Bud drop, however, was significantly higher than at the 74 degrees root temperature.

Conclusons:—From a comparison of the responses of the Belmont and veitchii plants to root temperature treatments it appears that the former is more drastically inhibited in growth by low temperatures than is the latter. The results also indicate that even at root temperatures as high as 82 degrees the Belmont remains very productive.

It can be concluded also that increases in light intensity and length of day, as well as increases in air temperature, tend to offset the retardation to growth and the foliage chlorosis caused by low root temperatures.

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Using a Short Interval of Light During Night to Delay Blooming of Chrysanthemums

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ABSTRACT

This material will be published in full elsewhere.

THE experiment described in this abstract was stimulated by the work (1939 unpublished) of Borthwick and Parker on the effect of a short interval of illumination during the dark period on prevention of flower bud initiation in Biloxi soy-beans. The plants used by these investigators were grown on 16-hour days until the start of their experiment. They were then all placed on 8-hour photoperiods and divided into five groups, receiving 0, 1, 5, 15, and 30 minutes of artificial illumination of approximately 160 foot candles at the mid-point of the 16-hour dark period. After 4 days of treatment all plants were returned to 16-hour photoperiods for about 2 weeks, after which they were dissected. No flower buds were formed on any plants in treatments involving interruption of the dark period, but were formed on all plants receiving uninterrupted 16-hour dark periods.

In the present experiment the chrysanthemum varieties used were Mrs. H. E. Kidder, Josephine Byrnes, Cornelia, and Gold Coin. Sixty plants of each variety were used in each treatment. They were selected for uniformity from among about 500 plants growing in 3-inch pots. All plants were exposed to the normal photoperiod existing during the course of the experiment. The treatments used involved interruptions of the dark period and consisted of (a) two interruptions, one at 10:00 p.m. and the other at 2:00 a.m.; (b) one interruption at 11:45 p.m.; and (c) control receiving no interruption. All interruptions of the dark period consisted of 45 minute applications of Mazda light at 32 to 60 foot candles. The lights were automatically controlled and the experiment started on September 6. Treatments were effectively screened from one another. Where the dark period was interrupted by a single light interval, blooming was delayed in the variety Mrs. H. E. Kidder for 29 days, and in Josephine Byrnes for 32 days as compared to the controls. The two light periods delayed the same varieties for 20 and 26 days respectively.

Soon after the plants which had received normal day length were commercially mature, 20 from each variety in all treatments were sampled individually. Determinations were made of size and number of flowers, of number of stems and leaves, and also of green and dry weights of stems and leaves. The 40 unharvested plants of each variety that had been receiving interrupted dark periods were equally divided into two lots. The original schedule of treatments was continued on one of these lots and the interrupted dark periods were discontinued on the other lot. On December 10, none of the Cornelia or Gold Coin plants that had received any light during the dark periods were blooming.

At the time of sampling it was found that as a result of interrupting the dark period, plant height was less in all varieties except Gold Coin than that of the plants receiving uninterrupted dark periods. This difference resulted even though the plants remained vegetative and accumulated far more total dry weight than did those receiving no dark period interruption. Two interruptions of the dark period were somewhat more effective than one for increasing the dry weight, but were not so effective in delaying bloom or retarding elongation.

Ethylene Injury to Cut Flowers in Storage

By D. Victor Lumsden, *U. S. Horticultural Station, Beltsville, Md.*

Abstract

This material will be published in full elsewhere.

EXPERIMENTS at the United States Horticultural Station, Beltsville, Maryland, with the cold storage of various cut flowers have demonstrated that the quality of the air in the cold storage room can influence the duration of salability of the flowers. Distinct injury has been noted to carnations, roses, snapdragons, and narcissus when they are stored in closed storage rooms with apples. It has been established for some time that ethylene emanates from ripening apples, and that this gas in even very small amounts can be extremely damaging to ornamental plants growing in a greenhouse. The work reported demonstrates that the injury manifestations in cut flowers when stored with ripening apples in a closed space are identical with those shown by cut flowers when stored in the presence of fresh air with ethylene added.

The effect of apple emanations on cut flowers in cold storage rooms was most pronounced at the highest storage temperature used, 70 degrees F, and the lower the storage temperature the slower was the injury. At all storage temperatures, however, the cut flowers in the presence of ripening apples or of ethylene alone always showed a shorter life than flowers that were stored free from ethylene.

The work at Beltsville also showed that at least some carnation varieties can be cut in the tight bud stage and yet they will open in perfect condition if they are stored in a room free from ethylene. On the other hand ethylene injured carnations in the bud stage in storage so that they never opened, and within 24 hours looked wilted and discolored.

When carnations were stored in a refrigerated room at 32 degrees F in which there were no apples, flowers both in full bloom and in bud presented a much better appearance than comparable lots from a storage temperature of 50 degrees when all lots were brought out of storage and given temperature conditions simulating the living room of a home.

A Species Hybrid of Calendula, Its F_2 Population and Its Tetraploid

By Charles Weddle, *Cornell University, Ithaca, N. Y.*

CALENDULA OFFICINALIS L. is a rapid growing annual, fill-in crop for retail florists but has never been extremely popular because of obvious faults in type of growth. The leaves are abundant and soft and the stems are short and fleshy. The keeping qualities of the flower are poor. New varieties improving upon these undesirable qualities have long been needed.

Calendula suffruticosa is a little known annual from the Mediterranean region. It is a small diffuse plant, woody at the base with small single yellow flowers usually less than 1½ inches in diameter which are borne on long slender peduncles. The leaves are dark green and crenate dentate. The center of the flower is yellow whereas that of *C. officinalis* may be yellow or a reddish brown.

Calendula flowers have peculiarities which make pollination very easy. The ray florets are pistillate and fertile, the stigmas being two lobed. The disk florets are perfect but female sterile, the styles being capitate. The heads are protogynous, making self pollination very improbable, although they are self fertile when pollinated from older heads on the same plant. The pistils are receptive with styles extended for the first day the flower is open. The second day the styles have retracted and the pollen is shed over a period of 3 or 4 days following. This mechanism makes emasculation and bagging unnecessary when plants are grown in the greenhouse where there are no insects.

In the summer of 1939 crosses were made between the double greenhouse Calendula (*Calendula officinalis*) vars. Ball's Lemon Queen and Ball's Gold and *C. suffruticosa*. The hybrids show considerable heterosis as indicated by the following average height figures for the three types when grown in a cloth house at Ithaca.

	Average Height (Inches)
Calendula officinalis	31
Calendula suffruticosa	36
Calendula officinalis x *C. suffruticosa*	41

The stems of the hybrids are long, quite firm, strong, and graceful. The leaves are dark green, intermediate in size, and are crenate dentate as are those of *C. suffruticosa*. There are fewer leaves on the stems than on those of *C. officinalis* and the stems are less sticky.

The flowers of the hybrid are very distinctive. They are single and yellow with two rows of ray florets and the centers are yellow or brown depending on the color of the eye in the parent officinalis plant, that is, the brown eye is dominant over the yellow eye in the F_1. The coloring varies from a pale lemon yellow to a rich chrome yellow and often there are concentric circles of the different intensities of yellow in the heads which gives them a distinctive charm. Hybrid plants grown in the greenhouse in pots, in the cloth house, and in the open

produced flowers continuously from the time they came into flower until either thrown out or killed by frost.

In the summer of 1940 F_2 populations were grown, and the inheritance of two character pairs was studied, namely, doubleness-singleness and the brown eye-yellow eye pair. As has been mentioned, brown eye or brown center is dominant to yellow eye in the F_1. If the flowers of the parent *Calendula officinalis* plant had brown centers, all the F_1 plants had brown centered flowers; whereas if both parents had yellow centered flowers, the F_1 flowers were yellow eyed. Singleness of the flower heads is dominant as all the F_1 plants bore single flowers.

The F_2 resulting from the selfing and sib-crossing of F_1 brown eyed plants produced the following segregations of types.

Single brown eye........	71
Single yellow eye.........	15
Double brown eye........	3
Double yellow eye........	3
Total......	92

It will be noticed immediately that the 86 to 6 ratio of singles to doubles closely approximates the 15–1 ratio as is expected for duplicate factors. The ratio of 74 to 18 is wider than the expected 3 to 1 ratio of the monohybrid, but Table I shows that the observed data fits the hypothesis that duplicate genes are responsible for singleness and that a single pair is responsible for brown eye.

TABLE I—SHOWING THAT DUPLICATE GENES ARE RESPONSIBLE FOR SINGLENESS AND THAT A SINGLE PAIR IS RESPONSIBLE FOR BROWN EYE

Calendula suffruticosa $D_1D_1D_2D_2\ yy$ X *Calendula officinalis* $d_1d_1d_2d_2\ YY$

$D_1d_1D_2d_2\ Yy$

$15\ D < \begin{matrix} 3Y = 45 \text{ Single Brown eye} \\ 1y = 15 \text{ Single Yellow eye} \end{matrix}$

$1\ d < \begin{matrix} 3Y = 3 \text{ Double Brown eye} \\ 1y = 1 \text{ Double Yellow eye} \end{matrix}$

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	O	C	O–C	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Single Brown eye	71	65	+6	36	.6
Single Yellow eye......	15	21	–6	36	1.80
Double Brown eye.	3	4	–1	1	.25
Double Yellow eye..	3	2	+1	1	.50
	92	92			$X^2 = 2.61$

P = .5 to .3

Table II shows the results of crossing the F_1 brown eye back to the double recessive, the yellow eyed double *Calendula officinalis*. Although the population is small, the data again fit the hypothesis.

After producing two crops of seed the F_1 plants were cut back, shifted to larger pots and treated with colchicine by inverting the plants in solutions of .16 and .20 per cent for 5 hours. Subsequent growth produced several shoots and flowers which appeared to be

TABLE II—RESULTS OF CROSSING F_1 BROWN EYE BACK TO THE DOUBLE RECESSIVE

F_1 Brown eye $D_1d_1D_2d_2$ Yy × *Calendula officinalis* Yellow eye $d_1d_1d_2d_2$ yy	O	C	O–C	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Single Brown eye	15	15	0	0	0
Single Yellow eye	18	15	+3	9	.6
Double Brown eye	5	5	0	0	.0
Double Yellow eye	2	5	−3	9	1.8
	40	40			$X^2 = 2.4$

P lies between .5 and .3

tetraploid judging from the stomata and pollen grain measurements given below.

	F_1 diploid (Microns)	Tetraploid (Microns)
Average length stomata	75	100
Length pollen grains	78	119

All the F_1 plants treated bore light yellow flowers with the concentric circles of lighter yellow. On the tetraploid stems resulting from treatment, sectors of uniform dark chrome yellow appeared in the flowers. Such chrome rays when self pollinated set seed which produced tetraploid chrome flowered plants. Not all of the tetraploid stems or tissue, however, produced chrome flowers.

The tetraploid flowers when pollinated among themselves produced a good set of seed. A large percentage of the resulting seedlings were tetraploid. The tetraploid flowers differ from the diploid by having slightly larger heads with considerably larger centers. The tetraploid plant differs from the diploid by having thicker, broader, darker green leaves. It has all the grace and character of the diploid form and, if it breeds true, will be a valuable garden flower. If double forms segregate (theoretically the tetraploid should produce 1 in 256 if pairing is random and there is no chromatid crossing-over), a new type will arise which will have stronger, more graceful stems.

For the tetraploid which, since it is fertile, may be considered a synthetic species, being an amphidiploid of a species hybrid, the name *Calendula officicosa* is proposed. A taxonomic description by Dr. G. H. M. Lawrence of the Bailey Hortorium follows: X *Calendula officicosa* (*Calendula officinalis* L. x *C. suffruticosa* Vahl).[1]

Tall free-branching annual; stems glandular-puberulent, subligneous, longitudinally striated: leaves sessile, minutely scabrous on both surfaces, margins strongly undulate and glandular-ciliate, remotely and acutely serrulate, apex apiculate; cauline leaves auriculate, the lower and middle ones broadly oblanceolate-oblong, upper ones lanceolate-oblong; heads 2½ to 3½ inches across; involucre 2-rowed, outer series longer than inner, densely glandular-pubescent; ray florets 3-toothed apically, lemon yellow; disc florets lemon yellow to Brazil red, anthers orange; achenes glandular pubescent.

This hybrid may be distinguished from *Calendula officinalis* L. in

[1]X *Calendula officinalis* hyb. nov.

the non-viscid character of the herbage, the more woody stiffer stems, the undulate and serrulate leaves with apiculate apices and the cauline ones auriculate at the base. From *C. suffruticosa* Vahl it is readily separated by its larger and more vigorous habit, broader leaves and much larger heads.

Chromosome counts were made for *Calendula officinalis, C. suffruticosa,* the hybrid and the tetraploid. Although Lundegardh (1) records 14 pairs of chromosomes for *C. officinalis,* the count for the material studied of both species, *C. officinalis* and *C. suffruticosa,* is 16 pairs, and for the hybrid 16 pairs, quite normal pairing appeared to be the rule in the material studied. The count for the tetraploid is approximately 32. Irregular pairing, however, makes it very difficult to determine the exact number.

Conclusion

Although it is too early safely to predict the value of either the diploid or the tetraploid form, it is felt that either is superior to *Calendula officinalis,* in type of growth. In the diploid form the back crosses to *C. officinalis* have yielded double-flowering plants with heads as large as the parent type. From these, true breeding types should arise with longer, stronger stems and less soft foliage.

It is believed that the tetraploid will prove as valuable as any colchicine-induced tetraploid yet reported, for theoretically it passes all the requirements, namely, it is an amphidiploid of a species hybrid with a relatively low chromosome number still and is fertile. There remains only to determine if true breeding varieties of the commercial types can be obtained, and this appears quite probable.

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The Control of Damping-Off by the Use of Sphagnum for Seed Germination

By Claude Hope, V. T. Stoutemyer, and A. W. Close,[1]
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THROUGH the use of living sphagnum moss as a medium for germination of seeds of about 2,500 species of plants at the United States Plant Introduction Garden, Glenn Dale, Maryland, over a period of 15 years, complete control of damping-off (2) has been obtained. This continued freedom suggested appraisal of the value of live sphagnum as a seeding medium in other respects, and of the possibility of substituting the much cheaper and more generally available dried, commercial sphagnum.

Search through standard horticultural literature has revealed very few instances of the use of sphagnum for seed germination. Burbidge (1) recommended living sphagnum for germinating seeds of orchids and *Nepenthes.* Hatfield (8) favored the use of a 1/16 inch layer of fine dried sphagnum over soil for seeds of ericaceous plants and for very fine seeds. Craig (3) suggested essentially the same method. Morrison (7) used dried sphagnum to cover seeds of azaleas sown on compost. Doran (4) compared a mixture of equal parts of sand and sphagnum, a like mixture of sand and peat, sand, and soil, for the control of damping-off. His results showed that the first three gave very good control with little difference between them.

In the experiments set forth herewith, dried, baled commercial sphagnum was compared with locally gathered living sphagnum and various more convential media. Reports are presented on a variety of seeds germinated on these media, both in the greenhouse and in coldframes at the United States Plant Introduction Garden at Glenn Dale, Maryland. Choice of material was so made as to cover a wide taxonomic range and to include species generally regarded as particularly susceptible to damping-off.

Experimental Data

The preparation of the flats with sphagnum was identical for both the living and the dried sphagnum, except for a slight moistening of the latter, and was the method outlined by Close (2). Briefly it follows: the sphagnum was rubbed through a sieve of hardware cloth having three meshes to the inch. The seed flats used were made of new white pine, 20 by 10 by 3 inches, and with the usual provision for drainage. In most of these tests, a mixture of two parts of imported peat to one of sand in the bottom of the flats provided a moisture-retaining substratum for the sphagnum. The surface of this lower layer was 1¼ inches below the top of the flat. The loose shredded moss was added to fill the flat, then leveled and firmed to bring the surface ½ inch below the top, care being taken at this stage that the sphagnum

[1]The authors gratefully acknowledge the assistance in certain phases of this study of Mr. Donald Dreisbach of the Hillculture Division of the Soil Conservation Service.

was not moist enough to compress easily. As a final step, the flats were well watered, sometimes before, sometimes after, sowing.

The soil mixture was made of one part of sand and three of composted sod loam which had been steam-sterilized some weeks before and stored in a bin. In the first experiment, the mixture received no disinfecting treatment of any kind. The sand medium consisted of washed river sand to which Dunlap's (6) simple two-salt nutrient solution (1 teaspoonful of potassium nitrate and 1 teaspoonful of superphosphate per gallon of water applied in an amount sufficient to saturate the material) was applied before sowing. The sand and peat mixture consisted of two parts of imported peat rubbed through a quarter-inch screen to one part of washed river sand.

With all sowings in these tests, the seeds were broadcast over the surface and received no covering other than a pane of glass placed over the top of the flat. Until germinated they were protected from direct sunlight on an open bench in a propagating house. As the seedlings developed, air was admitted gradually.

In the first experiment, the comparisons were made between living and dried sphagnum, soil, sand, and the sand and peat mixture. One-third of each flat was devoted to a different seeding medium, which was again divided in half by a line of sand to provide duplicate plots. In each plot a counted or weighed sample of seed was sown on April 17. The seedlings were counted 19 days after sowing, on May 6, and again 33 days after sowing, on May 20. The flats were held under observation for several more weeks, but there was no appreciable change. The graphs set forth in Fig. 1 are drawn from the combined seedling counts of both plots of each medium. They show the ratio between the best total for each species, considered as 100 per cent, and all other totals for that species.

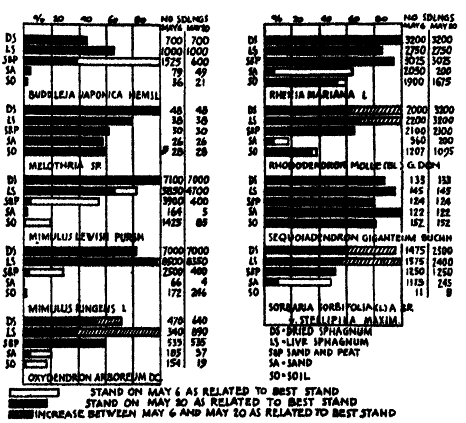

FIG. 1. The effect of unsterilized media on germination and damping-off survival in the greenhouse. The number of seedlings on the medium giving the best germination for a given species, disregarding date of count, is taken as 100 per cent for that species.

Spontaneous attacks of damping-off, which spread rapidly from the center of infection, were observed in the following: *Buddleia japonica, Mimulus Lewisii* and *M. ringens*, and *Sorbaria sorbifolia* on sand, soil, and sand and peat; *Oxydendrum arboreum, Rhexia mariana*, and *Rhododendron* on sand and on soil. The difference shown in Fig. 1 between the stands of May 6 and May 20 gives a measure of the extent of this loss. In no case were

attacks observed on either of the sphagnum media, although there were on them some slight losses of undetermined origin in *Mimulus Lewisii* and *M. ringens.* As shown in Fig. 1, seeds of several species continued germination on sphagnum after May 6.

When small clumps of plants injured by damping-off were transferred to other locations, new typical centers of infection developed except on the sphagnum. On this medium, occasionally, a plant or two was infected and killed at the point of inoculation, but never did the infection spread in the typical fashion.

On these unsterilized seeding media, it is clear that sphagnum, either living or dried, was superior from every point of view. Furthermore, dried sphagnum was fully the equal of living sphagnum. In fact, the plants were actually larger and greener in the former, suggesting that the products of disintegration were stimulative.

In the second experiment, the seeds were sown in a similar way, but on soil, sand, and sand and peat which had been subjected to steaming in the flats for 45 minutes at a pressure of about 50 pounds. Flats of living and dried sphagnum, not steamed, watered with Dunlap's two-salt solution before seeding, were included. All flats were kept in the same propagation greenhouse, but, as the season advanced, the temperatures were somewhat higher than those prevailing during the first experiment. The seeds of *Buddleia* and *Mimulus* were sown on May 10, and the others on July 10, but the method was identical for both sowings. The results are shown graphically in Fig. 2.

Damping-off occurred only in pepper sown in the peat and sand medium and in *Linaria* and *Trachelium* sown in sand. Inoculations were made as before on the various media in these trials after the seedlings had emerged, but were not successful, probably because the seedlings had hardened and passed the most dangerous period.

The two most satisfactory media were sterilized soil and sphagnum, particularly those to which nutrients were

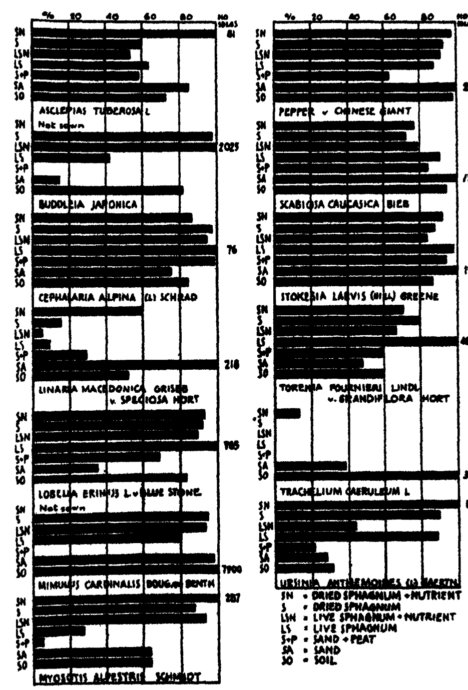

FIG. 2. Relative stands of seedlings on unsterilized sphagnum and on sterilized media after 30 days in the greenhouse.

added. This is especially true of the seeds of *Buddleia japonica, Lobelia Erinus, Mimulus cardinalis* and *Torenia Fournieri*. Dried sphagnum, both with and without nutrients, showed a slight superiority over the corresponding living sphagnum. The only failure on sphagnum in all these trials was experienced with seeds of *Trachelium caeruleum* as shown in Fig. 2. Its germination could not be considered good on any medium, and it is believed that a slight drying at a critical time was responsible for this failure. However, from a sowing of the same lot of seed made in November on dried sphagnum, there was good germination. In the sand and peat mixture, steaming seems to have produced some change that inhibited the germination of most seeds. Sand made a fair showing in this trial, but in several cases the number of seedlings produced was lower than in the other media.

In April 1940, dried sphagnum was given a rigorous trial in a small unheated greenhouse. A layer about half an inch thick was placed over unsterilized garden soil with a high humus content. The seeds were sown thickly in strips about an inch wide and an inch apart. After the sowing, and at occasional intervals of 5 to 7 days, nutrient solution was used instead of water. The situation was such that the flats could be attended only early in the morning or late in the afternoon. In other years, under similar circumstances, with either the same soil or builder's sand, a high proportion of the seedlings was killed by damping-off. Unfortunately, in this sowing no comparisons were made with other media, but the results were so highly successful as to warrant comment. In 40 lots of seed belonging to the genera *Adonis* 2 spp., *Alonsoa* 3 spp., *Amberboa, Ammi, Arnebia, Asperula, Boltonia, Brachycome, Browallia* 4 spp., *Centaurium, Charieis, Collinsia* 3 spp., *Crepis, Downingia, Eucnide, Felicia* 2 spp., *Gamolepis, Hebenstreitia, Heliophila, Ionopsidium, Mimulus* 6 spp., *Nemesia, Nolana, Penstemon,* and *Trachelium,* germination was very good with all but *Arnebia, Asperula, Hebenstreitia,* and *Charieis.* Only a few seeds of each of these were available. The seedlings were held in these flats until they could be transplanted to the open garden. Only one center of damping-off appeared, in one of the rows of *Mimulus;* it spread so slowly that after 2 weeks it was not more than 2 inches across. It is worthy of note that the seeds of *Trachelium caeruleum* in this sowing did not germinate until a month later, but at that time a very good stand was obtained.

So much success had attended the use of sphagnum in the greenhouse that it seemed worth trial in the coldframe. Accordingly, a frame was selected in which damping-off organisms had been so active earlier in the season that they destroyed all sowings made at that time. Colorimetric determinations indicated a pH of 4.3 for the soil.

On July 22, four plots, each 6 feet wide, were laid out. Dried, baled sphagnum, screened as outlined above except that the preliminary moistening was omitted, was spread loosely to a depth of about ¾ inch on two of the plots and about ¼ inch on one plot and well watered down with a fine spray. The fourth plot received no sphagnum. Immediately after, the seeds were planted in duplicate with random arrangement in bands 1 inch wide and 30 inches long, spaced 3½ inches apart. To avoid the chance that the concrete walls of the frame

would affect the results, adequate space was left at the ends and sides. A light covering of sphagnum was placed over the larger seeds in the sphagnum plots, and a covering of soil was used for the same seeds in the soil plot. On July 26 another plot was added, adjacent to the soil plot. In this case the seeds were sown on the soil but received a covering of sphagnum which varied in thickness according to the size of the seed. Dunlap's nutrient solution was applied to one deep sphagnum plot 2 days after sowing and repeated three times at about 5 to 7 day intervals. After sowing, the frame was closed tightly with glass sash, which in turn was covered with coarse burlap shade. As soon as most of the seeds had germinated, the sash was replaced by a screen wire shade. Unusually high temperatures prevailed during the period between August 2 and August 10. A maximum thermometer in the frame registered over 100 degrees F on several occasions.

The kinds of seeds sown, the resulting numbers of seedlings counted on August 21, and the rank of the plots are shown graphically in Fig. 3. There was little evidence of post-emergence damping-off, but numerous observations gave positive evidence of pre-emergence attacks in the two plots where the seeds were in contact with the soil.

The margin by which sphagnum surpassed unsterilized soil in this trial was most impressive. In fact, the difference was that between a successful germination and a virtual failure. This same difference was reflected in the character of the growth of the plants. Only in a few scattered tufts of plants was the growth on the soil plot equal to that of sphagnum plus nutrient. In the plot where the seeds were sown on soil and covered with sphagnum, few of the seedlings made good growth, possibly because the roots failed to penetrate the soil and there was too little sphagnum to provide adequate moisture.

The number of surviving seedlings seemed to be increased by the application of a weak nutrient solution to the sphagnum. It is possible that the superior stand on the thin sphagnum likewise may have been due to nutrients diffusing upward from the soil. The seedlings on the thick layer of sphagnum which did not receive nutrients were definitely inferior in appearance, although, on the whole, their germination was satisfactory.

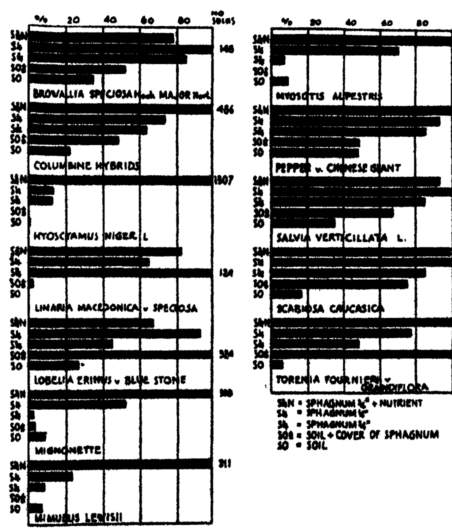

Fig. 3. Relative stands of seedlings on commercial sphagnum and on contaminated soil after 31 days in the coldframe.

As the first experiment in the coldframe drew to a close, a somewhat more extensive trial was inaugurated, designed to permit a comparison with soil under conditions more favorable to the latter. Plot 1 contained dry sphagnum in a layer approximately ¾ inch thick; Plot 2 sphagnum ¼ inch thick; Plot 3 received sphagnum only as a covering for the seeds. Two soil plots were unsterilized. Plot 4 received no treatment whatsoever. The seeds for Plot 5 were dusted with Semesan (30 per cent hydroxymercurichlorophenol) and after germination the plot received three applications of this substance in water in accordance with the manufacturer's recommendations. Plot 6 was freshly sterilized by steam pan 5 days before sowing. The positions of the plots were assigned by lot. Plots 3 and 4 adjoined the plots of the previous experiment. Plots 1, 5, and 2, in the order named, were in another frame which had not been sterilized for several years. Plot 6, for convenience, was in still another frame. In this test all plots received the Dunlap nutrient solution. On August 19 seeds of 29 species were sown, as before, in bands in duplicate in random order.

After sowing, the frames were closed with glass sash and shaded as before. For the following three weeks the weather was cloudy almost without a break, with light, intermittent rain and moderate temperatures ranging in the frame from a minimum of 63 degrees F to a maximum of 97 degrees F between August 19 and 30. From then until September 16 the minimum was 43 degrees (during the night of September 16) and the maximum 93 degrees. Even during the last two weeks of this experiment, there was very little sunshine.

With such ideal conditions for the growth of young seedlings, germination was uniformly good in all plots. No damping-off was observed in any of the following: *Begonia semperflorens* Link and Otto var. Vernon; Columbine hybrids; *Delphinium,* Belladonna strain; *Hyoscyamus niger; Linaria macedonica* var. speciosa; *Mimulus Lewisii;* Pansy, English strain; Pepper var. Chinese Giant; *Petunia* var. Double Fringed; *Philadelphus Delavayi* L. Henry; *Salvia verticillata; Scabiosa caucasica;* Stocks var. Early Giant Imperial; Tomato var. Marglobe; *Verbascum longifolium* Ten.

Attacks of damping-off occurred in the following instances:

Browallia speciosa var. major	Plots 3, 4, 5
Cabbage var. Early Flat Dutch	Plot 5
Celery var. Giant Pascal	Plot 3
Lobelia Erinus var. Blue Stone	Plot 5
Mignonette	Plots 4, 5
Myosotis alpestris	Plot 5
Pinus Banksiana Lamb.	Plots 1, 2, 4, 5, 6
P. resinosa Ait.	Plots 1, 2, 4, 5
P. Strobus L.	Plot 1
Sequoiadendron giganteum	Plot 4
Snapdragon var. Giant Tall	Plots 4, 5
Torenia Fournieri	Plot 5
Verbascum Lychnitis	Plot 5
Zinnia var. California Giants	Plot 5

Even though the coniferous seedlings in sphagnum, Plots 1 and 2, were attacked, there was little spread from the original centers, nor was there much loss in Plot 6. Damping-off exacted a much higher toll in Plot 5, treated with Semesan, but, even here, the spread was not serious. It is possible that the seedlings had passed the most susceptible stage before conditions became favorable to damping-off. For the most part, a few more seedlings were obtained in the steam-sterilized soil and subsequent growth here was appreciably better. The poorest plot was the one receiving the Semesan treatment, both in number of seedlings and in subsequent growth.

Only a few departures from this pattern are worthy of note. *Philadelphus Delavayi,* which showed very low viability and slow germination, was much better in all three plots using sphagnum. The vegetables, cabbage, pepper, and tomato, showed almost no choice between media.

Experience with the use of living sphagnum for seeds that germinate slowly has shown that damping-off is prevented even after several months. The living sphagnum, however, tends to grow and thus submerge the seedlings. Observations on the suitability of dried sphagnum in this respect have been limited. In one instance a species of *Swertia* germinated without incident about two months after sowing.

To test the keeping qualities of sphagnum, two flats of dried, and two of living sphagnum in ¾ inch layers over unsterilized sand and peat were prepared and watered on August 10 as if for immediate sowing. One flat of each was watered with the two-salt nutrient solution. They were covered with panes of glass, set away on a light bench, and kept moist. On November 8 each flat was marked off into six equal plots of 6 by 4 inches and sown in duplicate with measured quantities of seed of snapdragon, petunia, and torenia. The condition of the surface of the dried sphagnum appeared to be better than that of the living, although the latter had grown little. There was another application of nutrient solution to all flats immediately after sowing.

The number of seeds sown per sample and the percentage germination as determined December 10 are shown in Table I. No post-emergence damping-off was observed in any of these plots. The same lots of petunia and snapdragon seed, when sown on freshly prepared dried sphagnum at the same time and handled in the same manner,

TABLE I—STANDS OF SEEDLINGS AFTER 1 MONTH ON UNSTERILIZED SPHAGNUM PREPARED 3 MONTHS BEFORE SOWING

	No. of Seeds Sown	Seedlings Produced (Per Cent)							
		Living Sphagnum		Living Sphagnum Plus Nutrients in August		Dried Sphagnum		Dried Sphagnum Plus Nutrients in August	
Petunia, Balcony strain	750	24.0	21.9	26.8	25.9	35.7	33.1	29.6	34.4
Snapdragon	325	46.2	51.7	40.6	33.5	57.8	51.4	55.1	54.2
Torenia Fournieri	975	92.8	74.9	75.4	75.4	63.6	83.1	90.3	72.3
Means	—	60.2	51.8	52.1	50.6	52.5	59.8	62.5	55.6

yielded germination percentages of 35.2 and 69.9 respectively. No reason has been assigned for the reduced germination on the old surfaces.

In order to test further the capacity of sphagnum to inhibit the spread of damping off, one-half of each of a series of 12 flats was filled with untreated soil taken from the soil plot used in the first coldframe experiment. The other half of six of the flats was filled to within ¾ inch of the top with the same soil. Then a layer of ¾ inch of screened dried sphagnum was added. The two halves were adjusted to the same level and the junction between the soil half and the sphagnum half carefully closed so that nothing separated the two media. The remaining six flats were filled in the same way except that the sphagnum layer was only ¼ inch thick. Each half of each flat was sown on November 10 with equal but separately measured samples of seed. Four flats were sown with petunia and snapdragon seed; two on each thickness of sphagnum. Similar comparisons were made with two flats of *Myosotis alpestris* and two flats of *Exacum affine.*

In Fig. 4, the soil and sphagnum plots are compared for emergence and damping-off losses 45 days after sowing. For the most part emergence was poorer on the soil.

Post-emergence damping-off took almost all seedlings of *Exacum affine* on soil. A large portion of the petunia seedlings on two soil plots was killed by attacks of damping-off. One soil plot of myosotis likewise suffered heavy losses. Some losses on soil occurred in the other flats of petunia and in all those of snapdragon. There was no evidence of spread into sphagnum in any flat, nor were there any losses on it that could be attributed to damping-off. No distinction could be made between the two thicknesses of sphagnum.

By disregarding the thickness of the sphagnum layers, four replications are available for estimating the standard errors of the mean differences between the stands of petunia and snapdragon on sphagnum and soil. The mean difference between the two with petunia was 428.50 ±

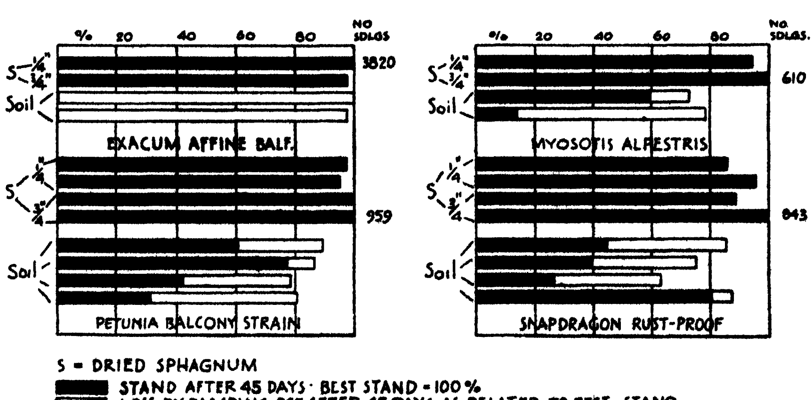

FIG. 4. The effect of contaminated soil and of commercial sphagnum in contact with contaminated soil on germination and damping-off in the greenhouse.

99.12 plants in favor of sphagnum. The mean difference with snapdragon was 338.75 ± 100.13 plants, also in favor of sphagnum. In spite of the few replications, the consistent trend of the data shown in Fig. 4 together with the fairly large mean differences give a reasonable assurance that the sphagnum prevented losses of seedlings after germination.

In the use of sphagnum at Glenn Dale over a period of several years, it has been demonstrated repeatedly that seedlings germinated on live sphagnum may be kept alive for months in the original seed flat with very little care. It appears after one season's experience with dried sphagnum that the same may be expected of it. Certainly seedlings of a number of species have been held successfully on it for 4 months.

Sphagnum had two advantages over most media not shown in the experimental data given above. It permitted the removal of either small or large seedlings for transplanting with a minimum of effort and a minimum of injury to the roots. Small seedlings were merely lifted out. Larger ones were easily pulled out. It permitted great latitude in watering. In the greenhouse it required very little water. In the coldframe daily watering was necessary, but it could be done without fear of the unfavorable reactions that accompany overwatering in soil. Furthermore, rains did not harm the surface.

Discussion

Judged purely from the standpoint of the control of damping-off, sphagnum is greatly superior to the other unsterilized media tried. Compared with sterilized soil under favorable conditions, its only advantage is simplicity. Furthermore, contaminations of sterilized soil are always possible.

Sand as a medium has been recommended by Dunlap (4), but in the trials at Glenn Dale, it has not furnished adequate protection against damping-off unless sterilized. When sterilized, it does not appear to have any particular advantages over sterilized compost. Furthermore, it does not hold water as well as either sphagnum or compost. Mixtures of peat moss and sand have been recommended as seeding media by Wiggin (8). However, the mixture tried at Glenn Dale has been inferior to sphagnum.

For the home gardener and the small greenhouse operator, the use of sphagnum obviates the expense of soil sterilization and the uncertainty of chemical treatment in seedling cultures. When it becomes necessary to germinate seeds with which the gardener is not familiar, sphagnum is helpful. Should the seeds fail to germinate immediately, they are readily accessible for examination and recovery, if need be, for stratification or other stimulative treatment. Preliminary tests indicate that dried sphagnum may be prepared by machinery for sowing in large-scale operations.

Without sterilization of seed or substrate, and with little attention to watering, sphagnum has given as good results as any other good medium regardless of treatment. The diversity of plants used in these tests, covering a great taxonomic range, promises wide suitability of sphagnum to seed of various kinds. In the other requirements of a

germinating medium, it is always equal, and generally superior, to soil and to sand.

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The Effect of Organic Materials and Other Treatments on the Growth of Delphinium Species

By K. E. Wheeler, *Cornell University, Ithaca, N. Y.*

THE investigations reported in this paper were undertaken to determine the effect of certain organic materials and other treatments on the growth and flowering of *Delphinium elatum* hybrids and *Delphinium grandiflorum.*

Materials and Methods

Genesee silt loam, which tested pH 7.2–7.3 by means of a quinhydrone potentiometer; low in P and K by the Morgan (1) and Spurway (2) methods but relatively high in NO_3, which had been brought in from a nearby abandoned field was thoroughly mixed with 25 and 50 per cent by volume of German peat moss and leaf mold (decayed maple leaves) in four different plots. All plots were separated by board partitions set 12 inches deep in the soil. One additional plot received no organic matter. Each plot was subdivided into eight divisions (plots) and each treated as follows: two plots treated with 1 pound of ground limestone; three plots treated with ¾ pound of sulfur and four plots untreated. The purpose of the lime and sulfur treatments was to study the influence of different H ion concentrations on the growth of the plants in relation to the organic matter mixtures. Each subdivision measured 5 by 4 feet and was planted in July, 1939 to four plants of *Delphinium elatum* hybrids, (Giant Pacific variety) and two plants of *Delphinium grandiflorum.* The plants were started from seed in the spring of 1939 and grown in 3-inch pots until given experimental treatment. No fertilizer was added at the time the plants were set or at any time during the first season.

Results

The effect of peat and leaf mold on the growth of *Delphinium elatum* hybrids during the spring of the second season are shown in Table I. From Table I it can be seen that the addition of leaf mold to the soil

TABLE I—The Effect of Peat Moss and Leaf Mold on the Growth and Flowering of *Delphinium elatum* (Spring, Second Year)

Treatment		Mean Height (Inches)	Mean No. of Leaves	Mean No. of Florets	Mean Dry Weight (Grams)
Soil alone	Check	37.9	62.3	126.3	36.4
	Lime	29.9	65.4	194.0	44.5
	Sulfur	38.4	39.2	115.0	29.0
25 per cent German peat moss	Check	31.5	61.5	105.0	30.4
	Lime	32.4	61.7	119.3	24.1
	Sulfur	32.2	35.4	62.0	17.0
50 per cent German peat moss	Check	30.0	55.8	101.7	22.8
	Lime	36.8	66.0	139.7	30.5
	Sulfur	31.0	45.4	81.6	16.1
25 per cent leaf mold	Check	44.4	97.7	361.3	96.6
	Lime	35.4	81.7	268.0	81.1
	Sulfur	37.5	79.9	246.3	62.7
50 per cent leaf mold	Check	46.7	150.3	740.7	121.8
	Lime	44.1	108.7	444.4	137.1
	Sulfur	41.2	95.8	415.6	104.3

TABLE II—CHANGES IN pH AND NITRATE NITROGEN DURING SECOND YEAR OF PLOTS AMENDED WITH PEAT AND LEAF MOLD

Treatment		pH	NO_3	(Ppm.)*
		May 15	May 15	Sept. 15
Soil alone	Check	7.28	5.00	2.0
	Lime	8.00	5.10	2.0
	Sulfur	6.68	5.00	2.0
25 per cent German peat moss	Check	7.28	1.25	0.75
	Lime	8.22	1.20	0.75
	Sulfur	6.72	1.30	0.75
50 per cent German peat moss	Check	7.19	1.00	0.50
	Lime	8.21	1.25	0.50
	Sulfur	6.72	1.50	0.50
25 per cent leaf mold	Check	7.35	3.50	2.0
	Lime	8.40	3.80	2.0
	Sulfur	7.10	4.00	1.5
50 per cent leaf mold	Check	7.60	4.00	2.5
	Lime	8.60	4.50	2.5
	Sulfur	7.49	3.50	2.7

*These plots not fertilized in July.

gave a marked increase in the growth of the plants over both the control and peat plots. When peat was added to the soil the plants showed poorer growth than the plants in the soil alone. The size of the leaves, the size and number of stems were all increased by the addition of leaf mold to the soil. In general, lime seemed to give beneficial effects both with the peat and leaf mold, indicating that an alkaline soil may be beneficial for delphinium. However, the soil data in Table II show that is not entirely a matter of H- ion concentration.

From Table II it can be seen that the peat plots treated with limestone had a pH of 8.2 to 8.3, while the leaf mold plots showed a pH only slightly above this (8.4 to 8.6+), yet the growth of *Delphinium elatum* in leaf mold plots was markedly greater than in peat. The pH of all plots remained practically the same throughout the second year. Although the data indicate that lime was beneficial to growth of delphinium there was no good correlation between pH and growth. From Table II it can be seen that the nitrate level of the leaf mold and soil mixture was higher than that of the peat-soil mixture, but slightly lower than the control soils. Thus, at least with the peat and leaf mold plots there was a fairly good correlation between nitrate and growth. Plants growing in peat-soil mixtures showed definite N-deficiency symptoms during the entire growing period in the spring of the second year. Those in leaf mold soil mixtures gave no indication of nitrogen deficiency. The increase in growth of the plants in the leaf mold plots over the control indicates that with the addition of organic matter to the soil, the plants are able to use nitrates more efficiently than in soil alone, since the control plots showed a slightly higher nitrate content than the leaf-mold plots, yet did not give as good growth as the plants in soil and leaf mold mixtures. Soil data the first year showed the same nitrate trend as the second year. The pH of the peat-soil mixture was considerably lower the first year. In fact, the 1–1 mixture of peat soil treated with sulfur showed a pH value as low as 5.91. Other treatments in the peat soil mixture showed low pH values during the first year. It is possible that there may have been some carry-over in effect from the previous season.

Growth After Cutting Back

After the plants were harvested in the early summer of the second year one plot of each of the lime and sulfur treatment and two of each of the check plots in each soil-organic mixture as well as the soil alone were fertilized with 1 pound of a mixed fertilizer (5–10–5 grade). This was done to raise the nutrient level. Two weeks later nitrate tests were made of soil samples from the treated plots. Sodium nitrate was then applied in different amounts, depending on the amount of nitrate present. The purpose of the fertilizer (sodium nitrate) was to adjust the nitrate content to the same level in all plots. The nitrate level which resulted ranged from 3.5 to 4.0 parts per million.

TABLE III—The Effect of Fertilizer Additions to Peat and Leaf Mold Plots Upon the Second Growth of *Delphinium elatum* During the Season of 1940

Treatment		Mean Height (Inches)		Mean No. of Flowers		Mean Fresh Weight (Grams)	
		No Fert	Fert	No Fert	Fert	No Fert	Fert
Soil alone	Check	4.8	29.9	13.8	123.5	65.1	345.8
	Lime	6.3	15.4	27.5	40.0	87.8	217.1
	Sulfur	2.9	27.8	3.8	68.7	112.1	242.1
25 per cent German peat moss	Check	4.8	28.2	15.0	116.7	105.6	224.3
	Lime	2.5	31.1	7.5	145.8	94.5	244.6
	Sulfur	4.3	24.5	18.8	61.0	100.0	153.1
50 per cent German peat moss	Check	5.6	25.9	15.6	81.7	80.3	289.2
	Lime	7.8	29.8	36.0	158.5	105.1	469.4
	Sulfur	3.4	31.8	1.2	116.3	46.5	249.2
25 per cent leaf mold	Check	5.3	28.0	20.3	295.3	233.8	455.6
	Lime	4.1	28.3	26.5	526.1	209.9	545.7
	Sulfur	4.0	32.8	10.0	303.8	175.0	550.0
50 per cent leaf mold	Check	4.9	28.2	55.0	369.3	261.4	633.6
	Lime	5.8	35.8	3.5	908.5	250.4	903.3
	Sulfur	6.6	30.3	30.0	346.0	245.0	569.5

The effect of the addition of fertilizers to peat and leaf mold plots on the second growth of *Delphinium elatum* hybrids are shown in Table III. The data in Table III show that the addition of fertilizers greatly increased the second growth of *D. elatum* hybrids. *D. grandiflorum* responded only slightly to the same treatment. The increase in leaf production of *D. elatum* hybrids in the fertilized plots over the unfertilized plots was only very slight, whereas the average increase in height was in many cases nearly six fold. Fertilization increased flowering to an extent of 10 to 20 fold in most of the treatments. The fresh weight was also greatly increased by fertilization. The NO_3 level of the unfertilized plots was low during the second growth period, the average ranging from 2.7 to 0.5 part per million (Table II). The P and K levels of the unfertilized plots were also low during this period.

Since the unfertilized plants produced a large number of leaves, but failed to elongate, except in a few plants, this would indicate that the unfertilized plants did not receive sufficient nutrients for stem elongation. These data strongly suggest that poor growth of the second

crop of delphinium is frequently experienced by growers may be due to a lack of sufficient nutrients in the soil.

Summary and Conclusions

From two years study of the effect of organic materials together with lime and sulfur treatments it was found that the addition of leaf mold to the soil gave increases in growth of both species of delphinium used. Leaf mold was found to be definitely superior to peat moss. Under the conditions of the experiment, there was indication of beneficial effect of lime, but there seemed to be no good correlation between growth and H-ion concentration. Second growth of *Delphinium elatum* hybrids was greatly increased by the addition of fertilizers at the time of cutting back in summer, while *D. grandiflorum* was only slightly influenced by fertilization at this time.

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The Reaction of Thirteen California Species of Delphinium to Powdery Mildew[1]

By GUSTAV A. L. MEHLQUIST, *University of California, Los Angeles, Calif.*

DURING the past four years a large number of varieties and strains of the common garden delphinium, as well as many related species, have been tested at this station in an attempt to obtain selections resistant to powdery mildew *Erysiphe polygoni*. As there are at least 16 distinct species of delphinium native to California some of which grow in areas adjacent to those where mildew is troublesome, it was decided to include them in the trials. This report deals only with the results obtained with these native species.

Since most of these species require two years or longer from seed to flower, mature plants of several species in south and central California were dug in their native habitats in the summer of 1939 and transferred to pots. All species native to California, except *Delphinium scopulorum,* go completely dormant following maturity of seeds and remain so until late winter or early spring when growth is resumed again as soon as the weather permits. Therefore the plants collected were only watered once immediately after being potted and then left dry in the lath house until the arrival of the winter rains. *D. scopulorum,* being the one exception, was grown from seed as it generally flowers the first season and apparently never goes completely dormant unless the temperature goes below freezing.

In the spring of 1940 as soon as the plants were a few inches high some of them began to show signs of mildew although no inoculation had been made. The source of infection probably was a single plant of a commercial garden variety grown on the same table. Within a few days all species except *Delphinium scopulorum* were infected. After a few weeks some species were completely covered with mildew whereas *D. scopulorum* was still free. The difference among the several species with respect to susceptibility was so striking that it was decided to test all species of delphinium native to California the following year.

In the summer of 1940 collection was made throughout the state until plants had been obtained of all species known to occur in California. So far as practicable several collections were made of each species in order to cover possible variation within the species. The plants were handled in the same way as the previous year. As soon as they were ready for inoculation they were transferred from the lath house to a cold frame where the test could be made without interfering with other operations in the lath house. The different accessions were placed in the frame at random so that most species occurred in several places. The frame was covered with lath shades as previous experience

[1]I am indebted to Professor H. L. Mason, University of California, Berkeley, Prof. C. C. Epling of Univ. of California, Los Angeles, Dr. C. B. Wolf, Rancho Santa Ana Botanic Garden, Mr. Carl Gerharty of the Los Angeles County Forestry Department and many members of the state and federal forestry departments for their most generous assistance in locating and collecting much of the materials used in this study.

had shown that infection is generally obtained more readily under partial shade. Two species *Delphinium Andersoni* and *D. pauciflorum* and the northernmost accession of *D. nudicaule* failed to grow sufficiently to be used in the test. As these accessions came from the northeastern section of this state where the winter temperature is considerably lower than in this region, it is probable that their winter chilling requirement was not satisfied here during the mild winter of 1940. *D. Parishii*, from the Mojave Desert, apparently was not adapted to the unusually heavy rainfall here for all the plants succumbed to stem canker caused by an *Ascoshyta sp.* The remaining 13 species went through the tests.

Early in March the plants were sprayed with a suspension of spores from a few commercial delphiniums carried over the winter in the field. Little effect from the inoculation was noted until early April when, during a few warm days, the mildew made rapid progress. Late in April the most susceptible species were completely covered with mildew and had stopped growing, but *Delphinium scopulorum* was still free. However, a few young plants of *D. scopulorum* had been retained in the greenhouse where they were grown next to some plants *D. variegatum* and *D. uliginosum* that were badly infected with mildew. Here the plants of *D. scopulorum* showed slight infections of mildew on the leaf petioles but none on the leaf blades. As soon as the plants of *D. variegatum* and *D. uliginosum* were removed, the mildew made no further progress on *D. scopulorum*.

The results of the tests have been summarized in Table I. As the

TABLE I—CLASSIFICATION OF SPECIES OF DELPHINIUM WITH RESPECT TO SUSCEPTIBILITY TO MILDEW

Species	Number of Plants	Number of Accessions	Rating*
Delphinium californicum T. & G.	10	2	4
Delphinium cardinale Hook	36	4	2
Delphinium decorum F. & M.	18	4	4
Delphinium Hansenii Greene	32	6	4
Delphinium hesperium Gray	42	8	4
Delphinuim Menziesii DC.	13	2	4
Delphinium nudicaule T. & G.	18	5	3
Delphinium Parryi Gray	40	6	3
Delphinium Purpusii Bdg	5	1	2
Delphinium scopulorum var. *glaucum* Gray	23	1	1
Delphinium trollifolium Gray	11	3	4
Delphinium uliginosum Curran	10	1	5
Delphinium variegatum T. & G.	43	5	4

*Rating: 1 = very high resistance; 5 = very low resistance.

classification of the different species with respect to susceptibility to mildew was the same both years, the results for the two years have been combined in the table.

In the case of *Delphinium purpusii* the results may not be significant as only one accession of five plants was available for the tests. It is unfortunate also that only one accession was available of *D. scopulorum* for, although the number of plants involved was large enough to be conclusive, the distribution of this species is so wide, extending as it does from the high mountains of Southern California to Alaska, that these results are not necessarily a true measure of the behavior of the

species as a whole. It is interesting to note that the greatest resistance was shown by the only species of those tested that is not limited to California or adjacent states.

As shown in the table, *Delphinium cardinale* also proved to be rather highly resistant to mildew. This is fortunate as this species possesses at least two features in addition to mildew resistance which would be highly desirable to have incorporated in the garden delphinium. It seems to succeed very well in a relatively warm dry climate, and has a range of colors from golden yellow to deep cardinal red, two colors which are rare in the genus Delphinium. No such colors are as yet available in any of the common perennial garden delphiniums.

About forty F_1 hybrids from crosses between *D. cardinale* and the susceptible species *D. californicum* and *D. uliginosum* have been produced to date. All of these hybrids are almost as susceptible to mildew as the susceptible parents indicating almost complete dominance of the factors controlling this character.

Whether the resistance of either *Delphinium cardinale* or *D. scopulorum* can be transferred to the garden delphinium remains to be seen. The possibility also exists that there is more than one form of the mildew.

Summary

Thirteen species of delphinium native to California were tested for resistance to the mildew, *Erysiphe polygoni*. Resistance ranged from very high in *Delphinium scopulorum* var. *glaucum* Gray to extreme susceptibility in *D. uliginosum* Curran. Relatively high resistance was found in *D. cardinale* Hook, a fortunate circumstance as this species possesses several characteristics which are horticulturally desirable and may prove of value in the development of delphinium varieties particularly adapted for the Southwest. From the F_1 hybrids between *D. cardinale* and susceptible species obtained thus far, it is evident that susceptibility to mildew is a dominant character.

Response of Bulbous Iris to Preplanting Treatments

By D. Victor Lumsden, *U. S. Horticultural Station, Beltsville, Md.*

Abstract

This material will be published in full elsewhere.

INVESTIGATIONS were carried out with bulbous iris at the United States Horticultural Station, Beltsville, Maryland, to determine if various storage temperatures, some of which are frequently employed prior to planting to accelerate flowering of the bulbs, could cause a failure of well-developed buds of these plants to open. This failure, known as "blindness" among growers, is sometimes quite prevalent in early forced bulbous iris. The experiment was concerned chiefly with the varieties Wedgewood and Imperator, stocks of which were secured from both North Carolina and Oregon. On August 28 different lots of 150 bulbs each were stored at the following temperatures for 5 weeks prior to planting: 55, 50, 45, and 32 degrees F, and common storage in a bulb house. During the same period one lot was stored for 1 week at each of the following temperatures in sequence: 55, 50, 45, 50, and 55 degrees; another lot, at 50 degrees for 3 weeks, followed by common storage for 1 week and then back to 50 degrees for 1 week; a third lot, at 32, 45, and 50 degrees for 1 week each and then 55 degrees for 2 weeks. An additional set of conditions for 150 bulbs was 50 degrees for 2 weeks followed by 32 degrees for 1 week and then 50 degrees again for 2 weeks, and finally, one lot was held for 3 weeks from August 28 in the bulb house and then at 32 degrees for 2 weeks prior to planting.

All of the bulbs given the storage temperatures mentioned above were planted 30 bulbs to the flat on October 3. They were then forced in a cool house with a day temperature of 50 to 55 degrees and a night temperature of 45 to 50 degrees. Most of the variety Wedgewood flowered between December 15 and February 15, while Imperator came into bloom mostly between March 1 and April 15.

The storage temperature treatments caused not only decided differences in the number of days for the bulbs to flower as was expected, but also lesser differences in other growth responses, all of which will be reported in full elsewhere. From no lot, however, were results obtained that gave any evidence that failure of buds to open or "blindness" was due to any of the storage temperatures given the bulbs prior to planting.

Problems in Forcing Easter Lilies

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

THE Easter lily is one of the more important potted plants and cut flowers grown in greenhouses. The problems involved in forcing them are numerous and methods of forcing and results in forcing vary among florists.

These experiments were made to determine the effects of (a) varying amounts of phosphate in the soil; (b) scale removal; and (c) light and temperature on vegetative growth, flowering and time of bloom of the Easter lily.

Lilium longiflorum giganteum was used in all experiments. Uniform bulbs were supplied by the Yokohama Nursery Company. All bulbs were planted during late November or December in a silty loam soil composted with one-fourth manure the year before using it. No fertilizer was added later. One bulb was planted to each 5-inch flower pot. The potted bulbs were placed close together on the greenhouse bench at a night temperature of 58 to 60 degrees. After 6 weeks they were spaced so that each plant had about 50 square inches in which to grow. They were grown under these conditions unless otherwise stated. Specific treatments and results appear under the various headings of the experiments.

The pots were not randomized but all bulbs of each treatment were grown adjacent to each other. Conditions for growth of all plants were as near the same as was possible to obtain in the greenhouse. The data were analyzed by Bessel's formula.

PHOSPHATE APPLICATIONS

According to Laurie and Poesch (1) heavy applications of phosphate to soils produce dwarf plants. The recommendations used on all types of soils by commercial florists appear to give varying results. Experiments were undertaken during 1937 and 1938 to determine the effects of varying amounts of superphosphate (20 per cent) upon the growth and flowering of lilies.

Twenty-five 7 to 9 bulbs were used in each treatment in 1937–1938 and 12 in 1938–1939. The treatments and results appear in Table I.

TABLE I—EFFECTS OF PHOSPHATE APPLICATION

Phosphate Added Per Bushel of Soil	Average Date First Flower Open	Average Height (Inches)	Average Number Flowers Per Stem
	Results of 1937–1938		
No phosphate	April 14 ±0.5	18.2 ±0.42	3.4 ±0.12
1 cup*	April 14 ±0.4	21.3 ±0.46	3.9 ±0.20
2 cups	April 16 ±0.4	19.6 ±0.68	3.3 ±0.15
3 cups	April 14 ±0.5	20.1 ±0.46	3.5 ±0.17
4 cups	April 14 ±0.3	20.9 ±0.49	3.7 ±0.17
	Results of 1938–1939		
No phosphate	April 8 ±0.9	17.0 ±0.61	4.5 ±0.19
1 cup	April 12 ±2.6	17.7 ±0.47	3.7 ±0.20
3 cups	April 20 ±1.0	17.1 ±0.54	4.0 ±0.15
6 cups	April 19 ±1.1	17.9 ±0.60	3.8 ±0.17
10 cups	April 17 ±1.1	17.1 ±0.46	3.9 ±0.15

*Measuring cup or 7.3 ounces.

It is evident that the phosphate had no effects during the first year. It delayed flowering and also slightly reduced the number of flowers per bulb during the second year. The length of stem was not affected even though 10 cupfuls (4.6 pounds) of phosphate were used per bushel. The delay in flowering time was associated with the delay in the initial growth. It was evident that the plants did not start and did not grow as rapidly at first when phosphate was added but later growth was equally rapid in all treatments.

Bulb Scale Removal

Bulbs held in storage or dried somewhat in shipment lose some outer scales. Scales are also lost in careless handling of the bulbs. These experiments were made to determine the effects of such scale loss upon the resulting plants. The scales were removed by breaking them at the base or by cutting the tops before planting. Forty bulbs were used in each treatment. The bulbs were size 9–11 and were planted November 20, 1934. The treatments and results appear in Table II.

Removal of scales or any part of them caused the plants to flower about 7 days later than those not treated. Uniformity of flowering was greatest when scales were removed. The stems were reduced in length in direct relation to the amount of scales removed. The number of flowers per bulb was reduced by the removal of scales or any part of them. The greater the number or amount of scales removed the more effective was the treatment on reducing the number of flower buds and height of the plants.

It is evident from these data that removal of scales or parts of them would be detrimental to flower production and should be avoided by commercial florists.

Similar results were obtained by White (2). He found the removal of a few loosely attached scales had no effect on the resulting growth whereas removal of many scales retarded growth.

Temperature and Artificial Light

Effects of Temperature in the Early Period of Growth:—The common practice among growers is to pot the bulbs and place them at a low temperature to start growth. Experiments have shown very little rooting occurs at temperatures below 60 degrees. White (2) found 62 to 72 degrees gave better rooting than higher or lower temperatures. This experiment was carried out to determine the effects of low temperature during the bud formation period on growth and bud formation.

TABLE II—Scales and Ends of Scales Removed

Treatment	Average Date of Bloom	Average Height (Inches)	Average Number Flowers Per Stem
Normal	April 7 $\pm$1.0	17.9 $\pm$0.37	5.2 $\pm$0.15
1/3 the scales removed to the base	April 13 $\pm$0.9	11.3 $\pm$0.24	4.0 $\pm$0.14
1/2 the scales removed to the base	April 14 $\pm$0.09	5.8 $\pm$0.15	1.4 $\pm$0.07
Top 1/2 of each scale removed	April 14 $\pm$0.14	14.3 $\pm$0.24	3.7 $\pm$0.12
Top 1/3 of each scale removed	April 14 $\pm$0.13	17.7 $\pm$0.09	4.6 $\pm$0.10

TABLE III—EFFECTS OF SHORT PERIOD OF LOW TEMPERATURE IN THE EARLY PERIOD OF GROWTH

Period at Low Temperature (Days)	Average Date of Bloom	Average Height (Inches)	Average Number Flowers
	1937–1938		
0	April 14 ±0.5	18.2 ±0.4	3.4 ±0.1
10	April 17 ±0.4	20.0 ±0.4	4.5 ±0.5
20	April 23 ±0.1	18.4 ±0.1	4.5 ±0.2
30	April 30 ±0.4	17.3 ±0.5	4.4 ±0.2
40	May 2 ±0.4	20.0 ±0.3	5.1 ±0.2
	1938–1939		
0	April 8 ±0.9	17.0 ±0.6	4.5 ±0.19
10	April 24 ±0.7	17.2 ±0.3	4.7 ±0.16
20	April 30 ±0.5	20.0 ±0.7	4.8 ±0.23
30	May 6 ±0.7	19.5 ±0.2	5.1 ±0.22
40	May 12 ±0.7	20.4 ±0.6	4.8 ±0.19

Ten 7 to 9 bulbs per treatment were potted on December 6, 1937 and a similar number in 1938. They were placed in the greenhouse at a temperature of 58 degrees at night. When the plants were 2 inches above the bulb 10 were placed at a temperature of 45 degrees at night for 10, 20, 30 and 40 days. They were returned to the higher temperature after the cold treatment. Results of the treatment for both years appear in Table III.

These data show the longer the potted bulbs were held at the low temperature the longer they required to flower. The low temperature treatment had no effect upon height of plants. The tendency was to produce more flowers at lower temperatures, but these data are insignificant.

The Effects of Light and Temperature During Forcing:—Many preliminary experiments indicated variability in the effects of electric light, in addition to normal day light, upon time of bloom. Light intensities of 35 and 100 foot candles were obtained by using Mazda bulbs and adjusting the height each week to give the proper intensity at the top of the plants. The treatment was given 6 hours each night starting

TABLE IV—EFFECTS OF ADDITIONAL LIGHT AT VARIOUS TEMPERATURES

Treatment	Average Date of Bloom	Average Height (Inches)	Average Number of Buds
50 degrees + 100 foot candles at 4 inches	April 20 ±0.7	28.0 ±0.4	3.4 ±0.11
50 degrees + 35 foot candles at 4 inches	April 27 ±0.8	27.5 ±0.5	3.5 ±0.12
50 degrees + 100 foot candles at bud	May 17 ±1.4	24.1 ±0.7	3.9 ±0.16
55 degrees + 100 foot candles at 4 inches	March 30 ±0.8	30.1 ±0.5	2.2 ±0.16
55 degrees + 35 foot candles at 4 inches	April 8 ±0.6	28.4 ±0.5	2.8 ±0.13
55 degrees + 100 foot candles at bud	April 28 ±0.9	22.6 ±0.9	3.6 ±0.19
55 degrees	May 9 ±1.0	17.0 ±0.3	4.4 ±0.23
60 degrees + 100 foot candles at 4 inches	March 25 ±0.3	30.7 ±0.3	2.7 ±0.12
60 degrees + 35 foot candles at 4 inches	March 28 ±0.5	32.9 ±0.4	2.4 ±0.14
60 degrees + 100 foot candles at bud	March 28 ±0.6	31.9 ±0.6	2.5 ±0.15
60 degrees	April 14 ±0.3	18.8 ±0.5	3.3 ±0.24
65 degrees + 100 foot candles at 4 inches	March 11 ±0.7	33.0 ±0.4	2.3 ±0.11
65 degrees + 35 foot candles at 4 inches	March 11 ±0.6	31.9 ±0.6	2.1 ±0.08
65 degrees + 100 foot candles at bud	March 13 ±0.5	33.0 ±0.5	2.3 ±0.02
65 degrees	March 11 ±0.6	29.2 ±0.3	1.8 ±0.19
70 degrees + 100 foot candles at 4 inches	March 10 ±0.4	22.5 ±0.4	1.6 ±0.09
70 degrees	March 9 ±0.3	20.2 ±	1.7 ±0.05

on some plants when they were 4 inches high and on others when the buds appeared. The data appear in Table IV.

Higher temperatures and additional light at lower temperatures caused earlier flowering and fewer buds per plant. The stem length was greatest at the 65 degree temperature. Both lower and higher temperature than 65 degrees produced somewhat shorter stems. Additional light reduced the period necessary for flowering at temperatures below 65 degrees but did not affect the time of bloom at higher temperature. Additional light increased the length of stem on all plants at the lower temperatures. The number of buds per plant was greatest at the lower temperatures.

Summary

Phosphate applications to the soil in which the bulbs were planted delayed flowering but did not reduce the length of stem. Removal of scales or parts of them from the bulbs reduced the number of flowers per bulb and the height of the plants. Low temperatures (50 degrees) during the early period of growth delayed flowering and tended to produce more flowers per bulb. The time for flowering was reduced as the temperature of forcing was increased from 50 to 70 degrees. Higher temperatures reduced the number of buds which developed. Artificial light in addition to normal day light hastened flowering when the temperature was below 65 degrees. It had no effect on the time of flowering at 65 degrees and higher temperatures. Additional light reduced the number of buds per plant.

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Some Factors Causing Fading in Color of Rose Blooms[1]

By J. C. Ratsek, *Texas Agricultural Experiment Station, Tyler, Tex.*

COLOR intensity of most hybrid tea rose blooms is high in the spring and fall and low in the summer. The summer fading of color has generally been attributed to the direct fading effect of bright sunlight and possibly high temperature on the color pigments in the flower petals. Studies at Tyler have shown that any effect these two factors may have had was mainly secondary. In fact, there was some indication that sunlight was necessary for the full development of the red color in Talisman blooms, but the major effect of sunlight and temperature was through their action on photosynthesis and growth.

Coombes (1) working with a number of plants including trees and shrubs found that ringing of a branch resulted in the appearance of anthocyan in the leaves and stems. He concluded that soluble carbohydrates which accumulated above the ringed portion of the plant favored the formation of anthocyan. Rose (4) found a direct relation between light intensity and pigment formation and concluded as did Coombes that increased light resulted in an increased amount of sugars which in turn permitted the formation of a red pigment in leaves and stems. Kosaka (3) working with the abutilon and other plants, found that in seedlings before photosynthetic activity had begun anthocyan formed in the stem in inverse ratio to the increment of growth. He found a similar but more narrow ratio for older plants because of photosynthesis. If however, leaves were removed, the ratio was again distinct. He concluded that anthocyan is present in abutilon in inverse ratio to the amount of transformation of nutritive materials available during growth or in direct ratio to the accumulation of nutritive materials or the products of photosynthesis.

In April 1940, established plants of hybrid tea roses, variety Talisman, were pruned in various ways to determine the effect of heavy and light pruning on bloom production. Plants were thinned to two to four strong canes which were then pruned to 4, 12, or 20 inches, or not at all. A fifth group of plants were neither thinned nor pruned. The first crop of blooms to open varied in color from nearly pure white to deep Talisman red. The 4-inch and the 12-inch pruned plants were pure white or pale yellow-pink. The 20-inch pruned plants were medium pink and the thinned — no-pruning and the no-thinning — no-pruning treatments were deep Talisman red. The lack of red pigmentation was still very evident in the 4-inch pruned plants in the second crop of blooms.

Willstatter and Nolan (5) and Currey (2) have shown that the red pigment of roses is cyanin, a cyanidin glucoside. Its formation in blooms as in leaves and stems probably depends upon an available supply of carbohydrate nutrient. Severe pruning removed wood containing stored carbohydrates probably present as a sugar since tests during the winter with plants at Tyler showed the absence of all

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starch. As buds forced and stems and leaves were formed, most of the available carbohydrates were used up and pigments failed to form.

In early June, 10 plants of Talisman were completely defoliated. Blooms that opened 4 days after defoliation were pale pink to white — a few were pinkish-yellow. To determine how definite the relation was between carbohydrate supply and pigment formation, a number of stems with buds at about the same stage of development were selected in early June. One-half the stems were defoliated to the ground. Both defoliated and non-defoliated stems were given the following treatments: stems with one bud, two buds, four buds, and six buds; stems with one bud given a 1½ per cent sugar solution through a leaf petiole; stems with one bud covered tightly with brown paper bag or with a glassine bag; stems with one bud covered with a brown paper bag opened on the north side. Ten stems were used for all treatments except the check — one bud treatments of which there were 50. Just before buds were completely opened they were picked and rated for red pigment development on the basis of a scale where 1 was white and 8 was deep Talisman red. The red pigment of a number of the deep colored blooms was extracted with alcohol and acidified with HCl to use for determining the No. 8 color in subsequent observations.

Table I indicates the results. In general, stems with leaves produced more pigment than those with no leaves. Additional sugar as sucrose seemed to increase pigment formation in the non-defoliated stems but

TABLES I AND II—EFFECT OF DEFOLIATION, NUMBER OF BUDS PER STEM, BAGGING, AND SUGAR SOLUTION ON BLOOM COLOR

Treatment	Number of Stems	Average Color*	Number of Blooms Per Stem	Number Stems	Average Color*
				No Leaves	
Leaves, 1½ per cent sugar solution	8	6.88 ±0.390	1	225	2.43 ±0.051
Leaves, 1 bud	36	6.22 ±0.228	2	48	2.38 ±0.089
Leaves, 2 buds	9	5.89 ±0.344	3	18	2.28 ±0.140
Leaves, 4 buds	9	5.89 ±0.389	4	6	2.17 ±0.518
No leaves, tight brown bag	10	4.60 ±0.253	12	4	1.25 ±0.189
				Leaves	
Leaves, tight brown bag	10	4.50 ±0.402	1	302	6.10 ±0.078
No leaves, 1 bud	44	4.54 ±0.157	2	81	5.10 ±0.113
No leaves, 2 buds	9	4.44 ±0.277	3	97	4.81 ±0.125
No leaves, open brown bag	8	4.38 ±0.358	4	81	4.72 ±0.125
No leaves, 6 buds	10	4.20 ±0.218	5	13	5.00 ±0.182
No leaves, 1½ per cent sugar solution	9	4.11 ±0.271	6	7	3.27 ±0.282
Leaves, 6 buds	10	4.00 ±0.359	7	8	3.25 ±0.179
No leaves, 4 buds	10	3.90 ±0.324	8	8	3.38 ±0.191
Leaves, open brown bag	10	3.90 ±0.376	9	9	3.56 ±0.381
No leaves, tight transparent bag	10	3.90 ±0.411	10	9	4.22 ±0.156
Leaves, tight transparent bag	10	3.60 ±0.284	12	5	2.40 ±0.334

*1 = white; 8 = red.

*1 = white; 8 = red.

not on the defoliated stems. The greater the number of buds on a stem the lighter the bloom color apparently the result of competition between buds for available carbohydrates. Covering the bud with a brown paper or glassine bag appreciably reduced the formation of pigments. This would seem that sunlight may be necessary for the full development of the red pigment. The fact that blooms of Talisman during

periods of cloudy weather are usually lighter in color than during periods of sunny weather would seem to substantiate this. It is not likely that the effect of the cloudy weather on photosynthesis would be sufficient to cause a reduction in red pigment because of a reduction of carbohydrates.

A second experiment was set up in July with the emphasis on bloom competition for carbohydrates with the attendant affect on pigment production. Thirty plants of Talisman were completely defoliated, some 50 plants were not. Stems were labeled as to the number of buds each contained and as they opened records were taken as before. Table II shows the results.

It is evident that defoliation greatly reduces the production of color pigments. Furthermore, there is a general decrease in bloom color with an increase in number of buds on a stem. Where several buds were growing on one stem, there was a difference between the color of the first buds to open and later buds. First buds were generally lighter in color as shown in Table III. This would seem to be due to the elimination of competition for the remaining buds as the first blooms were removed.

TABLE III—Color of Blooms Opening at Different Times on the Same Stem

Number Buds per Stem	First Bloom		Second Bloom		Third Bloom		Fourth Bloom	
	Number Observed	Average Color	Number Observed	Average Color	Number Observed	Average Color	Number Observed	Average Color
				No Leaves				
2	32	2.34 ±0.100	16	2.44 ±0.158	—	———	—	
3	8	2.13 ±0.191	5	2.20 ±0.148	5	2.60 ±0.295	—	
				Leaves				
2	58	5.05 ±0.133	23	5.22 ±0.212	—	———	—	———
3	44	4.18 ±0.135	31	5.48 ±0.185	22	5.14 ±0.176	—	———
4	31	4.39 ±0.178	24	4.92 ±0.264	15	4.93 ±0.309	11	5.00 ±0.341

In the final test of the season, hybrid tea roses of other colors were defoliated. Etoile de Hollande, a dark red, developed pale purple-pink blooms. Briarcliff, a deep pink, developed white to pale pink blooms. Julien Potin, a deep yellow, developed white to cream colored blooms. President Herbert Hoover, a two-tone, developed white blooms.

Discussion

It is evident that development of a deep color in roses is dependent upon available carbohydrate supplies. During the summer when many varieties may be much defoliated as a result of black spot infection, blooms are very much lighter in color than earlier in the spring when leaves were abundant. This was well demonstrated in two adjoining blocks of Talisman, one block of which was dusted regularly with a fungicide and a second block where no dust was applied. The blooms were extremely variable on the undusted plants, ranging from pale pink to deep Talisman red. Blooms on the dusted plants showed little variation with the exception of those stems that carried six to 12 buds.

It was noticeable that even when all the foliage was maintained on Talisman bushes the blooms were in general lighter in color in the summer than in the fall or spring. That this summer fading may be due to sunlight is possible. It is more probable, however, that with increasing temperatures there is an increase in wood growth. A competition is set up between growing points and blooms for available carbohydrates. If growth proceeds at the expense of cyanin formation, bloom color fails to develop to the proper intensity.

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Effect of Aeration on Growth of Hybrid Tea Roses

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It has been known for many years that most crops give poor growth when grown under anaerobic soil conditions. DeVilliers (2) reported that apple seedlings died within a few weeks in soil containing 1 to 3 per cent oxygen. Different species are known to vary in their oxygen requirement. Zimmerman (6), reported tomato, salvia and ivy cuttings to have a higher oxygen requirement than willow which grew roots in water containing only 1 part per million of oxygen. Boynton (1), reported a marked decrease in the formation of new rootlets on apple tree root systems when the amount of oxygen in the soil atmosphere was reduced below 15 per cent. The growth of the top was also markedly reduced.

The experiment herein reported is a preliminary study of the effect of aeration on total linear growth of hybrid tea roses (Signora variety). All roses were budded on *Rosa multiflora* var. japonica cuttings. Fifteen plants of hybrid tea roses were used in each of the four treatments: (a) clay soil without aeration; (b) clay soil with forced aeration; (c) clay-peat mixture without aeration; and (d) clay-peat mixture with aeration.

A heavy type of soil known as Dunkirk silty clay loam was used as a base in all four treatments. Soil of this type is composed of very fine particles and under normal moisture conditions is poorly aerated. For the soil-peat mixture, American peat moss (Maine) was used. The proportion of the mixture was one part of peat moss to two parts of soil by volume.

The native soil was removed from four beds to a depth of 1 foot and replaced with the soil and the soil-peat mixture. The plots which were to be aerated had an additional 6 inches of soil removed from the bottom of the bed and three lines of 4-inch tile were laid lengthwise. The tile was covered with cinders, thus reducing the depth of the bed, so that the depth of the soil in which the roses were planted was the same in both the aerated and non-aerated treatments. In addition, glass wool channels, 3 inches in diameter, covered with hardware cloth, were connected to the tile every 2 feet and extended vertically to the surface of the soil. These channels were used to increase the aeration of the soil without causing it to dry out excessively. The soil and soil peat mixtures which were not to be artificially aerated were in direct contact with a well drained gravelly subsoil.

Air was forced through the tile for a 1 hour period each day (7 to 8 a. m.). Tensiometers as described by Richards (3) were used to measure the moisture tension range in the four treatments. Water was added as needed to keep the moisture tension between 5 and 20 centimeters of mercury. In this tension range only very minute cracks developed on the surface of the soil and did not seem to be a factor in aeration especially since the soil atmosphere samples were taken at a depth of 8 inches. Linear growth data and soil atmosphere analyses

TABLE I—EFFECT OF AERATION ON GROWTH OF HYBRID TEA ROSES

Bed	Treatment	Mean Linear Growth per Plant* (Inches)
I	Non-aerated soil	37.3
II	Aerated soil	68.4
III	Non-aerated soil-peat mixture	81.2
IV	Aerated soil-peat mixture	155.8

*Mean of 15 plants.

were taken over a 4 month growing period from June 18 to September 18, 1940.

The H-ion concentration of the growing media was determined by the Quinhydrone electrode method at the beginning and end of the experiment. At the same times soil analyses as described by Morgan (4) were made for NO_3, P_2O_5 and K_2O and no detectable differences in these elements were obtained in any of the four beds. The oxygen and carbon dioxide content of the soil atmosphere was determined by the Haldane method. Samples of the soil atmosphere were taken 8 inches below the surface by the method reported by Boynton (1) with a slight modification. Statistical analyses were carried out by the use of Student's method as revised by Livermore (3).

RESULTS

In Table I the mean linear growth per plant in inches is given for each of the four treatments.

By aerating the soil, the total linear growth per plant was nearly double that of the growth in the same soil without aeration. When the soil-peat mixture was aerated the growth was nearly double that of the non-aerated soil-peat plot.

The soil atmosphere analyses as taken from the four treatments are given in Table II.

The average carbon dioxide percentage in the soil atmosphere was not over 1.9 per cent. The non-aerated soil averaged 1.5 per cent lower in oxygen than soil aerated over the four month period. The non-aerated soil-peat mixture averaged .5 per cent higher in oxygen than the non-aerated soil. The average oxygen percentage of both plots which were aerated was nearly the same.

The increase in linear growth of the aerated treatments over the non-aerated ones was highly significant mathematically (odds greater than 9999:1). Likewise, the oxygen content was significantly higher.

TABLE II—EFFECT OF AERATION ON SOIL ATMOSPHERE

Bed	Treatment	Mean Soil Atmosphere Analyses*	
		CO_2	O_2
I	Non-aerated soil	1.5	18.8
II	Aerated soil	.3	20.3
III	Non-aerated soil-peat mixture	1.9	19.3
IV	Aerated soil-peat mixture	.6	20.2

*Mean of 17 determinations.

Discussion

Although the oxygen difference of 1.5 per cent between the aerated soil and non-aerated soil treatments was small, it is possible that the rose is sensitive to slight differences in oxygen concentration and may have responded to this small increase. There is also the possibility that the method of sampling did not adequately represent aeration conditions in the soil, in spite of the precautions taken to make sure that it did.

The difference in growth between the aerated soil and the non-aerated soil-peat mixture was not statistically significant. Therefore, it may be assumed that there was no difference in growth between these treatments. However, the oxygen content of the aerated soil averaged 1 per cent higher than that of the non-aerated soil-peat mixture. If aeration were the only factor involved, the aerated soil should have produced more growth than the non-aerated soil-peat mixture. In this particular comparison the H-ion concentration might have been a factor since the pH value of the soil was 7, while the soil peat mixture was 6. It is also possible that the aeration conditions were more uniform in the soil-peat mixture than the aerated soil. There may have been regions in the heavy soil which had a lower oxygen content than 20.3 per cent as shown by the test. These regions of lower oxygen content may not have been indicated by the method of sampling but yet may have been effective in limiting the growth.

The slight difference of .9 per cent between aerated and non-aerated soil-peat mixtures could hardly have been responsible for the great increase in growth in the aerated treatment. It is possible that the peat moss may have altered other factors and exerted other effects in addition to improving the aeration. Further investigations should be made under more closely controlled conditions of oxygen, carbon dioxide, temperature and moisture.

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Comparative Water Usage and Depth of Rooting of Some Species of Grass[1]

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THE growth of perennial or annual cover crops in orchards results in competition between the fruit trees and the cover crop plants for the nutrients and moisture that may be obtained from the soil. The fruit tree and the plants of the cover crop must obtain their supplies from those portions of the soil exploited by each. Whenever the two sets of roots are found interwoven or the development of one root system brings it into a portion of the soil already occupied by the other, the competition may result in injury to one crop or the other. This occurs in nearly every orchard when a cover — either of annuals or perennials — is grown, since the area seeded usually includes a portion of the area beneath which the roots of the fruit trees are growing.

Since considerable interest has developed regarding the use of grasses for orchard cover crops, the following study was undertaken in an attempt to find out what differences might exist in the amount of water taken from the soil by various species of grass. Ten species of grass were selected for study to determine any differences in the amounts of water used by each under the conditions of the experiment. The species grown were: Canada bluegrass (*Poa compressa* L.), Kentucky bluegrass (*P. pratensis* L.), smooth brome grass (*Bromus inermis* Leyss.), reed canary grass (*Phalaris arundinacea* L.), Chewings fescue (*Festuca rubra* L. var. *commutata* Gaud.), sheep fescue (*F. ovina* L.), orchard grass (*Dactylis glomerata* L.), quack grass (*Agropyron repens* L.), redtop (*Agrostis alba* L.), and timothy (*Phleum pratense* L.). The nomenclature is according to Hitchcock (2).

WATER USED BY GRASS SPECIES

The containers used for the growth of the cultures were 3-gallon iron pails that had an inside diameter of 10¼ inches. Each was filled to an approximate depth of 10 inches with sandy soil. The soil was then moistened to approximate field capacity. Eight containers were planted to each grass species using six or seven plant segments per pot. Three containers were left unplanted and used as bare-soil checks, no weeds were permitted to grow in them. In midsummer, one culture was removed from each species series and used for another test, so the data were obtained and the averages for each species were calculated from either six or seven cultures.

The containers were placed in the greenhouse as soon as the grass was planted and remained there from October 1st until late March when they were transferred to an unheated sash house where they were grown through the summer. At this time the grasses had all formed a sod covering the soil surface of the containers. The sash house into which the cultures were transferred was roofed with ordi-

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nary cold frame sash and the center ridge pole was about 7½ feet high, the sides being open to a height of 30 inches. Curtains of canvas were let down when necessary to keep the rain out and during clear weather the sides were open to provide ventilation.

Despite the ventilation provided by the open sides, air circulation was not so rapid within the house as it was outside, and on sunny days the air temperature was somewhat warmer inside than out. Since the containers were exposed to the air, the temperature within them undoubtedly fluctuated more widely than would similar soil under normal conditions in the orchard. The grass appeared healthy and normal, but fall growth was not resumed quite as early in the house as in plantings of the same species outside the sash house.

The cultures were given water once or twice a week depending on the season of the year and the amount of water removed from the soil. Semi-weekly waterings were given during late July and early August. Whenever a culture was watered, it was weighed and sufficient water was added to bring the weight up to the original weight taken just after planting time. The differences observed between species were pronounced and are presented in Table I.

TABLE I—AVERAGE NUMBER OF POUNDS OF WATER ADDED PER CULTURE

Grass	May 3 to May 27	May 27 to Jun 23	Jun 23 to Jul 18	Jul 18 to Aug 15	Aug 15 to Sep 8	Sep 8 to Sep 29	May 3 to Sep 29	Average Number of Inches of Water Lost (Transpired and Evaporated) From the Cultures, Bare Ground = 0
Timothy	6.7	7.5	8.7	8.7	5.6	5.1	42.3	−.4
Check, bare soil	6.7	7.0	8.9	9.6	5.7	5.2	43.1	——
Canada bluegrass	7.8	10.2	11.2	10.7	7.0	5.7	52.6	+3.0
Orchard grass	5.8	9.8	11.5	12.1	7.4	6.2	52.8	+3.1
Chewings fescue	6.3	11.0	12.6	12.5	7.5	6.4	56.3	+4.2
Sheep fescue	7.1	10.3	12.8	13.0	7.7	6.3	57.2	+4.5
Kentucky bluegrass	7.6	11.2	13.2	13.7	8.1	6.7	60.5	+5.6
Reed canary grass	6.5	11.8	13.5	15.3	9.4	7.2	63.7	+6.6
Quack grass	7.5	12.5	14.2	15.7	8.6	6.5	65.0	+7.0
Redtop	6.6	13.3	16.1	18.6	11.5	9.0	75.1	+10.2
Smooth brome grass	6.8	15.2	17.0	17.7	11.3	8.6	76.6	+10.7

The data show that the grass provided an effective mulching material which greatly reduced the amount of water evaporated directly from the soil surface. In the case of the timothy, the amount of water transpired from the leaves plus the amount evaporated from the surface of the soil was about the same as the amount of water evaporated from the containers with bare soil.

The amounts of water lost by transpiration plus evaporation from the soil vary but with no very large differences occurring between adjacent species when they are arranged in order as in Table I. If a classification seems desirable, the timothy cultures and the group which were left bare, constitute a group which required the addition of comparatively little water and the redtop and the smooth brome grass constitute a group which required the addition of comparatively large amounts of water. The remainder of the species can be considered as a rather broad intermediate group. Some of these, Canada bluegrass,

orchard grass, chewings fescue and sheep fescue, tend to use less water than do others such as Kentucky bluegrass, reed canary grass and quack grass. Under the conditions of this experiment, the average amount of water lost from the cultures of redtop and smooth brome grass was about 78 per cent more than the average loss from the timothy cultures and the group unplanted. The average water loss of quack grass exceeded Canada bluegrass, by nearly 24 per cent, which is a measure of the breadth of the intermediate group.

Before making any attempt to make recommendations as to the selection of grass species for orchard use, it should be emphasized that these data indicate the relative amount of water that these species will transpire plus that which will be lost from the soil surface beneath their cover under the particular conditions of this experiment. The major difference between these conditions and those in the orchard is that moisture was available for evaporation from the soil surface of the cultures a longer proportion of the time than would be the case in orchards unless the rainfall were more frequent and abundant than is normal in Michigan. Further, unless the grass rooted quite deeply, moisture loss at the rate recorded by these cultures would soon remove all the available water stored in the soil to a considerable depth. Thus, in the field, the amount of water available in the soil reached by the grass roots would seldom be sufficient to equal the amount that the grass is capable of transpiring. The amount actually removed from the soil would tend to be a function of the roots' ability to supply moisture rather than mainly a function of the transpiration rate of the leaves.

Depth of Rooting of Grass Species

Data were obtained not only on water use but also on the depth of rooting of the various grass species. These data show that there are considerable differences in the proportionate distribution of roots in depth as well as variations in the total weight produced. The grasses were grown for a period of one year in a series of galvanized iron boxes which were 4 feet deep and are described in more detail elsewhere (1). The soil in which they were grown was a sandy loam with its finer material mostly organic in character. Such a soil is open, with excellent internal drainage, is well aerated, and should permit the penetration of the grass roots at least to depths reached in most orchard soils. The soil containing the roots was removed in layers of 6 inches; the roots washed out, dried and weighed. The weights which were obtained from single containers for each species are recorded in Table II.

The data presented in Table III include the weights of roots in the bottom 2 feet of the containers, the total weights of fibrous roots and the percentages of the roots that are found in the lower halves of the containers. If the grass species are arranged in order, with the species having the smallest percentage of roots in the lower half of the container placed first, the actual weights of fibrous roots in the bottom half of the containers will also increase from the top to the bottom of the table. The only exception is redtop. The weight of the roots actually obtained seems considerably less than might be expected when 5.4 per cent of the roots are in the bottom half. This may be accounted for,

TABLE II—GRAMS OF DRY MATERIAL REMOVED FROM THE SOIL AT DIFFERENT DEPTHS, TOGETHER WITH THE WEIGHT OF THE DRY TOPS (GRAMS)

Grass	Tops	Fibrous Roots 0–6	Rhizomes 0–6	Fibrous Roots 6–12	Rhizomes 6–12	Fibrous Roots					
						12–18	18–24	24–30	30–36	36–42	42–48
Timothy	62.8	45.0	—	5.1	—	2.5	1.9	1.5	0.4	0.5	0.5
Canada bluegrass	84.2	35.6	23.8	8.1	—	2.8	2.3	1.8	0.9	0.4	0.1
Orchard grass	Winter	killed									
Chewings fescue	50.3	51.0	1.3	7.6	—	1.9	1.5	1.4	0.5	0.5	0.3
Sheep fescue	66.5	64.1	—	10.2	—	6.5	3.4	0.7	0.1	0.1	0.1
Kentucky bluegrass	58.9	50.4	10.3	8.1	—	4.7	1.7	0.7	0.3	0.4	0.4
Reed canary grass	48.1	31.0	13.3	6.4	—	2.3	1.9	1.6	1.6	0.9	0.8
Quack grass	40.1	40.0	25.6	17.2	4.7	3.5	2.7	2.5	2.1	1.4	2.5
Redtop	46.1	24.5	14.6	5.2	0.6	0.8	0.9	0.8	0.3	0.4	0.3
Smooth brome grass	59.4	50.4	6.1	20.1	—	12.5	7.9	6.3	4.4	3.4	2.0

TABLE III—THE RELATIVE DISTRIBUTION OF THE ROOTS IN THE UPPER AND LOWER HALVES OF THE CONTAINERS

Grass	Total Weight of Fibrous Roots (Grams 0 to 24 Inches)	Weight of Roots (Grams 24 to 48 Inches)	Per Cent of Roots in Lower Half
Sheep fescue	85.2	1.0	1.1
Kentucky bluegrass	66.7	1.8	2.6
Chewings fescue	64.7	2.7	4.3
Timothy	57.4	2.9	5.1
Redtop	33.2	1.8	5.4
Canada bluegrass	52.0	3.2	6.2
Reed canary grass	46.5	4.9	10.4
Quack grass	71.9	8.5	11.8
Smooth brome grass	107.0	16.1	15.1

however, by the fact that the total weight of roots of the redtop is the smallest recorded in the table.

On the basis of these data, three of these grass species are of questionable merit for orchard cover, namely smooth brome grass, quack grass and reed canary grass, since they have a larger proportion of their root systems in the lower half of the containers than do the other species. The larger the development of roots in the lower portion of the container, the greater the probable amounts of water which the grass might be expected to remove from the deeper portions of the soil.

Everyone has noticed that grass which receives sufficient moisture does not turn brown during the summer. Often we find portions of a seeding of a single grass species green when other parts are brown. The green portions are usually found where moisture is more abundant and the growth of the plants is not prevented by droughty soil conditions. Where plots of single grass species are grown on similar soil areas, some of the species plots remain green when others turn brown. In the orchard plots at East Lansing, the plots of smooth brome grass, quack grass and orchard grass remained green much longer than did those plots seeded to the two bluegrasses, the two fescues, timothy and redtop. The data recorded in Table III show that two of those grasses which remained green are deep-rooted and no data are available on the third. Since the grasses that turned brown are more shallow-rooted, it is suggested that observation of the color of the cover is a dependable method for determining whether a cover is

removing considerable quantities of moisture from the soil at the time of observation. If the cover is green and growing rapidly during July and August, the probability exists that it may prove a dangerous competitor of the fruit trees.

Competitive Effects of Sod in Orchards

The extent and character of the competition between the cover crop and the orchard trees are defined by the growth characteristics of the two kinds of plants. Roots of plants usually do not grow very rapidly in dry soil or even in soils where the amount of available moisture is very small. Data show that either the roots of well-established cover crop plants or the roots of fruit trees remove nearly all the available moisture from the upper soil during the dry periods which occur in Michigan nearly every summer. Consequently annual cover crops are unable to make much growth and sometimes die when they are seeded on areas underlaid by soil from which the water has been removed by the fruit tree roots, unless timely rains supply their needs. On the other hand, fruit trees are unable to extend their root systems into soil from which most of the water has been removed by the roots of other crops.

During periods when the soil is moist, roots may enter the space already occupied by the roots of another crop. After these are once established, they will continue to exist there, provided the plants from which they come are able to survive on the nutrients and moisture that they are able to obtain from the competitive zone and the soil below or beyond this zone. Thus crops seeded after the summer drought is broken are more likely to become established than those seeded in midsummer. Similarly, crops seeded in late spring or perhaps early summer are also likely to become well established before the droughts of summer commence. Under these conditions the cover crop competes with the fruit trees for the moisture and nutrients in the surface soil. Whether this competition will be harmful to the fruit trees will depend on the moisture reserves available to the fruit tree roots in the soil mass below the major root development of the cover crop. The amount and character of the summer rainfall is also an important consideration in determining the harmful nature of this competition.

The plants of a perennial cover when sown under the trees will extend their roots into the soil already occupied by the fruit tree roots, since they are usually seeded in late summer or in the spring when the soil is well supplied with moisture. Most of the perennial cover crops, in particular the grasses, are able to exist even though they may become quite dormant during periods of summer drought. When fall rains begin the soil again becomes moist and the grass resumes growth. This habit of growth makes it difficult for the trees to dislodge grass except where the shade becomes very dense. The perennial cover may reduce the vigor and productivity of the fruit trees unless the trees are able to obtain sufficient nutrients and moisture from the soil despite the competition. It is possible to supply any lack of nutrients without much difficulty by suitable methods of fertilizer application, but where soil moisture reserves are insufficient to supply the needs of the tree, it may prove impossible to supply the required water economically.

Thus, the character of the soil, the soil management program, the kind of fruit tree grown and the sort of cover crop all have marked effects on orchard yields. Apple and pear trees are recognized as being more tolerant of grass competition than are peach trees and grape vines, although the former are not immune to injury under some circumstances. Young fruit trees are more subject to damage than old ones probably because their roots have not penetrated so deeply as those of mature trees growing on similar soil. The likelihood of damage to the trees is also influenced by the rooting characteristics of the cover crop. Alfalfa is recognized as offering more severe competition for water than does bluegrass, because the alfalfa roots more deeply, remains green and grows actively throughout the summer and evaporates more water per acre than does the grass. On the other hand, the bluegrass may compete more actively with the fruit trees for nitrogen than does the alfalfa.

Suitable management practices, such as the use of mulching materials in the orchard or discing or mowing the cover at suitable times, may reduce the demand of the cover for nutrients and moisture and result in no damage to the orchard. Certain soils, such as loams which are underlaid by penetrable clay or silt, are usually supplied with large subsoil moisture reserves which, during drought periods of several weeks, enable the trees to secure moisture from horizons below the root penetration of all but the deepest rooted cover crops.

In many ways grass seems to be a desirable perennial cover for orchards. It gives a tight cover and effective protection against ordinary erosion. It does not evaporate as much water per unit area and the root system is not so deep as that of alfalfa and sweet clover. When a cover of an adapted species is once established it is dependable for long periods, provided reasonably favorable management is provided.

It seems evident from the data that there are marked differences in the extent of the competition furnished by the various grass species studied. The differences between the bare soil series and the grass species would have been more pronounced if a soil had been used which would not evaporate moisture at so rapid a rate. Undoubtedly, that soil characteristic, in conjunction with the presence of a dense protective mulch of dead grass leaves on the soil surface of the pots which sharply limited the evaporation of water directly from the soil, accounts for the fact that the timothy cultures lost less moisture by transpiration plus evaporation, than did the bare soil by evaporation alone. No data were obtained as to the relative proportions of evaporation and transpiration for any of the species.

On the basis of these data, it would seem that the use of smooth brome grass, quack grass and reed canary grass would be inadvisable in orchards, since they will transpire large quantities of water when it is available and further because their roots penetrate deeply enough so that they reach moisture reserves that do not seem so likely to be reached by the other species. Redtop, Kentucky bluegrass and the fescues will transpire considerable quantities of water when it is available but the data indicate that they do not penetrate so deeply. Timothy and Canada bluegrass seem to offer the least competition to the trees.

Nevertheless, they may not always prove the most effective species since neither species is adapted to all soil conditions found in orchards. After all, only adapted species can be grown in any particular environment, the choice must be made from those species which will furnish a permanent cover at the particular orchard under consideration.

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Further Studies on Factors Affecting the Forcing Performance of Easter Lily Bulbs

By Philip Brierley and Arthur H. Curtis, *U. S. Horticultural Station, Beltsville, Md.*

Abstract

This material will be published in full in the *Journal of Agricultural Research.*

PREVIOUS experiments at the United States Horticultural Station, Beltsville, Maryland, have shown that storage of Easter lily bulbs for 5 weeks at 50 degrees F exerts a marked stimulus to early growth and flowering. Bulbs of the Creole variety dug in Louisiana in early August 1938, and cool stored flowered in the greenhouse in February 1939. In the present trials Creole lilies were dug at six dates from June 16 to August 16, 1939, subjected to 50 degrees storage, or to other temperature treatments, shortly after harvest and flowered under glass. The bulbs from 50 degrees storage flowered successively from October 23, 1939, to January 28, 1940, according to date of digging; all other treatments included in the trial proved less effective in accelerating bloom. Combination of early harvest and 50 degrees storage permits new crop domestic bulbs to compete favorably in the winter flower market (November to January) with imported bulbs stored from the previous season for flowering at this period. Some of the bulbs dug in June were not sufficiently mature to respond to 50 degrees storage, and represented a commercial loss. The date of maturity of the bulbs, which may vary with season and with place, is the limiting factor in early harvesting for winter bloom.

Creole lily bulbs dug early and cool-stored early (July) flowered more promptly under glass than similar bulbs dug later and treated later (August), but when early and late harvested lots were stored at the same period (late) there was no real difference in response.

When seedling Easter lilies produced in four different States were forced with and without preplanting cool storage, bulbs grown in Louisiana flowered earliest, and lilies produced in Louisiana and California grew taller than those grown in North Carolina or Maryland.

In a comparative test of the forcing performance of Creole lilies of three grades of severity of mosaic disease, severely affected individuals were slower to come up and to bloom, much shorter, and bore fewer and smaller flowers, none of which were salable.

A Comparison of Grasses for Athletic Fields and the Effect on the Turf of Peat Incorporated with the Soil[1]

By J. A. DeFrance, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

IN 1933 a test was begun to compare turf developed from different grasses and grass mixtures under actual playing-field conditions. The points about which information was desired were: (a) the most wear-resistant grass among the common bents, bluegrasses and fescues; (b) the grasses or mixtures which grow well when not artificially watered; and (c) the effect of peat when incorporated into the top 5 inches of the seed bed.

An area 70 by 30 feet selected in the center of an athletic field at Rhode Island State College, was divided into 21 plats, each 10 feet by 10 feet. The plats were under test during seven playing seasons. Field hockey is played on this field continuously, mornings and afternoons, from early September until December. In spring and summer the traffic is not so heavy or severe.

Method of Procedure

Prior to May 1932 the field was covered by boulders, stones and native vegetation such as blueberry, briars, bayberry and other low-fertility plants and weeds representative of land in the northeastern states on which sites for athletic fields are usually located. Large rocks were blasted and removed and the area was plowed. As a level and uniform field was desired, the topsoil was removed from the cuts and fills and piled at the edge of the field. After the fill was made and rough graded with a road scraper the field was rolled with a heavy tractor. The loamy topsoil (pH 5.85) was uniformly distributed by use of a tractor and scoop, levelled with a road scraper, spring-tooth harrow and drag. A 4-inch layer of topsoil was all that could be afforded, even though a depth of 6 to 8 inches was considered a minimum over the yellow sandy subsoil. The field was temporarily seeded to rye in September 1932.

The area was plowed and harrowed in early September, 1933. Poultry manure was spread evenly over the field at the rate of ½ cubic yard per 1,000 square feet or approximately 12 tons per acre, except on the plats where peat was to be used. Hydrated lime was applied at the rate of 1 ton and superphosphate (20 per cent) at 1,000 pounds per acre. The area was harrowed four times to mix these materials thoroughly with the topsoil. Application of sulphate of ammonia and muriate of potash was originally planned but was omitted because the poultry manure available at the college farm was thought to furnish sufficient nitrogen and potash. That this idea was mistaken was later brought out by the yellowness of the seedlings, due undoubtedly to nitrogen deficiency.

Twenty-one plats of 100 square feet each were staked out in the center of the field. A ¾ inch layer of Swedish horticultural peat was

[1]Contribution No. 590 of the Rhode Island Agricultural Experiment Station.

applied and thoroughly mixed with the soil in plat A-7; 1½ inches with plat B-7; and 1½ inches of Connecticut peat with plat C-7. Sulphate of ammonia at the rate of 5 pounds per 1,000 square feet was applied to the peat plats as no manure had been applied to them. Sprague and Marrero (5) showed that organic matter such as peat could be substituted satisfactorily for manure, if the nutrient deficiencies are corrected by the addition of fertilizer.

Finished grading was done by hand raking with wooden rakes and rolling by hand in two directions with a water-ballasted roller. Strips of 2-inch wide lattice lumber were placed around each of the seedings to avoid any contamination or washing of seed from one plat to another. The plats were seeded September 30 with the different grasses and mixtures at the rates noted in Table I.

Each spring the area was raked and then rolled with a field roller. In early April a 10–6–4 fertilizer is applied at the rate of 500 pounds per acre. The sources of nitrogen were inorganic, from sulphate of ammonia; and organic, from cottonseed meal. Mowing was done once a week during the season at a height of 1½ inches and the clippings were allowed to remain until mid-September when the height of cut was lowered to 1¼ inches and the clippings removed. Quality factors considered in taking notes were as follows: color, density, vigor, uniformity, resistance to play injury, invasion of other grasses and weeds, drought injury, ruggedness of turf and general appearance.

Results and Discussion

Six days after planting, the ryegrass, Colonial bents and redtop had germinated. Two weeks after seeding, the stand ranged from 3 per cent in the creeping red fescue to 35 per cent in the velvet bent and 3 weeks later from 5 to 55 per cent. The rapidity of germination and per cent of stand was highest with velvet bent and lowest with fescue and bluegrass. There was very little difference in the rapidity with which redtop and ryegrass produced a stand when compared with Colonial bents. Velvet bent and the forms of Colonial bent including Rhode Island, New Zealand, Oregon and Astoria germinated as rapidly and produced as high a per cent of stand as where redtop and Pacey's ryegrass were used in the mixtures. Neither redtop nor ryegrass persisted for any length of time in the mixtures, while the Colonial bents and velvet bent were permanent. A comparison at the Rhode Island Agricultural Experiment Station (4) of ryegrass and redtop as nursegrasses for late planting proved the ryegrass much superior to the redtop. Pacey's ryegrass, as received in this country, is merely the small seed of perennial ryegrass separated out mechanically.

The creeping forms of Colonial, and velvet bent, due to their habits of growth, seemed not to get as firm contact with the soil as did Kentucky bluegrass and fescue. The age and maintenance factors undoubtedly play an important part in this respect. During the first two years of the experiment, velvet bent and the creeping forms of Colonial, such as Astoria, received very high ratings. Then they sent out runners or stolons which in the absence of close cutting and compost topdressing produced a brown fluffy matted mass of stems that were undesirable.

TABLE I—A Comparison of Grasses on an Athletic Field and the Effect of Peat Incorporated in the Soil

Plat	Grass Planted and Rate[d]	Average Relative Quality Factors†	Composition of Turf, 1940				
			Colonial Bent (Per Cent)	Kentucky Bluegrass (Per Cent)	Fescue (Per Cent)	Weeds (Per Cent)	Annual Bluegrass (Per Cent)
A 1	Rhode Island Colonial Bent, 3[d]	80	82	12	—	3	3
A 2	New Zealand Colonial Bent, Strain A, 3	73	61	33	—	2	4
A 3 N⅓	Oregon Colonial Bent, 3	67	50	32	—	8	10
A 3 S⅓	New Zealand Colonial Bent, Strain B, 3	71	60	25	—	5	10
A 4[a]	Chewing's Fescue, 3; Rhode Island Colonial Bent, 1	76	50	40	3	2	5
A 5[a]	Chewing's Fescue, 2; Kentucky Bluegrass, 1; Oregon Colonial, 1	90	61	34	2	1	1
A 6[a]	Chewing's Fescue, 3; Oregon Colonial Bent, 1	72	52	40	3	2	3
A 7[c]	Chewing's Fescue, 2; Kentucky Bluegrass, 1; Colonial Bent, 1; Pacey's Perennial Ryegrass, 2	95	48	34	15	1	1
B 1	German Bent, 3	75	55	35	—	4	6
B 2	Same mixture as on plot A 7	96	40	44	7	4	5
B 3	Prince Edward Island Colonial Bent, 3	75	53	39	—	5	3
B 4[a]	Kentucky Bluegrass, 3; Rhode Island Colonial Bent, 1	92	55	41	—	2	2
B 5[a]	Chewing's Fescue, 2; Kentucky Bluegrass, 1; Astoria Colonial, ½; Velvet Bent, ½	86	53	35	3‡	1	5
B 6[a]	Creeping Red Fescue, 2; Kentucky Bluegrass, 1; Oregon Colonial, 1	90	51	40	2	2	5
B 7[b]	Same mixture as on A 7	99	48	37	13	1	1
C 1	Velvet Bent, 3	73	17	37	—‡	3	9
C 2	Astoria Colonial Bent, 3	76	60	26	—	4	10
C 3 N⅓	Chewing's Fescue, 9	67	50	25	10	9	6
C 3 S⅓	Creeping Red Fescue, 9	66	51	27	9	9	4
C 4[a]	Chewing's Fescue, 3; Velvet Bent, 1	68	29	36	8‡	6	3
C 5[a]	Chewing's Fescue, 3; Astoria Colonial, 1	80	47	36	7	3	7
C 6[a]	Creeping Red Fescue, 3; Oregon Colonial Bent, 1	72	38	51	3	5	3
C 7[c]	Same mixture as on A 7	100	47	31	21	1	1

a = Plot received ¾ inch Swedish Peat incorporated with the soil.
b = Plot received 1½ inches Swedish Peat incorporated with the soil.
c = Plot received 1½ inches of Connecticut peat incorporated with soil.
d = Figure refers to pounds per 1,000 square feet.
* = North ⅓ had 1 pound Redtop; South ⅓, 2 pounds Ryegrass; Center ⅓ no nurse grass.
† = Comparative average of seven years quality notes and observations.
‡ = B 5 had 3 per cent Velvet; C 1, 34 per cent; and C 4, 18 per cent.

On the other hand, the varsity baseball diamond at Rhode Island State College planted with Piper velvet bent in 1936 has been maintained at a height of ½ inch with a putting green mower, and topdressed two or three times during the year at the rate of ¼ cubic yard of compost per 1,000 square feet. Under these conditions the turf is very satisfactory, stands the wear and tear, and does not become matted and fluffed up. Close cutting and an occasional topdressing are necessary to reveal the maximum beauty and utility of velvet bent. Occasional topdressings would undoubtedly benefit the other creeping types of bent grass and produce better rooting of the stolons and tend to keep them from matting and fluffing up due to the activity of traffic, and quick stops and starts on the part of the players. Athletic traffic of this kind has had very little harmful effect on the Kentucky bluegrass and fescue, or on the Colonial bents when well intermingled with fescue and bluegrass.

Colonial bents in mixtures with Kentucky bluegrass and fescue developed a very good, firm, rugged and uniform turf. This is the case not only where the mixtures were seeded but also on pure plantings of Colonial bent that are becoming invaded and intermingled with Kentucky bluegrass. Rhode Island Colonial bent when seeded with Kentucky bluegrass received a higher quality rating (92 per cent) than where used alone (80 per cent). In recent years Rhode Island bent has been the outstanding form of Colonial bent in these tests. Hitchcock (2) lists Rhode Island, New Zealand, and Prince Edward Island Colonial bent as noncreeping forms of *Agrostis tenuis,* and Astoria and Oregon Colonial bent as creeping forms.

The invasion of Kentucky bluegrass on the plats not seeded with it originally has been from 12 per cent on the Rhode Island bent plat to 51 per cent on the creeping red fescue-Oregon bent plat, and is becoming rather prominent on many of the plats, especially where fescues were planted, with the exception of the plats that received peat. That Kentucky bluegrass invaded and intermingled with the fescues and bents is fortunate because it appeared to be much greener and grew faster than the other grasses in the mixture during the fall playing season. In the three plats where peat was incorporated, the bluegrass has intermingled with the fescue and the bent grass to produce a firm, uniform, mixed turf consisting of about 20 per cent fescue, 50 per cent Colonial bent and 30 per cent bluegrass.

Fescues planted alone were not satisfactory. They appear to need the association of bluegrass, Colonial bent, or both, in order to become good turf-forming grasses for a fall athletic field. Fescue was more permanent in seedings on the peat plats than where no peat was used. Elsewhere it has gradually diminished for one cause or another. Longley (3) reports that an application of a two inch layer of peat well mixed with lawn soils before seeding produced a noticeable increase in growth as compared to the check plats.

Plat B-2 was seeded with the same mixture (fescue, Colonial bent and Kentucky bluegrass) used on the peat plats. The 7-year average of the quality notes (96 per cent) was close to that of the peat plats although the plats receiving 1½ inches of peat were slightly superior

(99 and 100 per cent).

Since the test plats are in the center of the field where play is heaviest, the turf is subjected to injury and divots are dug up and removed. Consequently, a certain amount of weeds naturally grow on the bare soil before the grass can recover and fill in the vacant areas. The weeds consisted of broad-leaved plantain, dandelions, knotweed, crabgrass, clover and annual bluegrass. Clover is considered a very undesirable weed in athletic field turf because of its tendency to produce a slippery surface. No more than 2 per cent clover appeared in any one plat. The largest amount of plantain (5 per cent) and the largest amount of crabgrass (2 per cent) was recorded on the most severely damaged plats. Only traces of dandelion and knotweed were observed. Annual bluegrass was rather vigorous in cool weather and filled in well on bare spots. As high as 10 per cent was noted on the plats of Astoria and Oregon Colonial. Velvet bent had 9 per cent while Rhode Island and Prince Edward Island bent had only 3 per cent. It is interesting to note that the creeping forms of Colonial bent, and velvet bent were invaded more by annual bluegrass than the non-creeping forms of Colonial bent. Very few weeds (1 per cent) appeared on the peat plats.

A composite soil sample of the area tested pH 5.5 indicating only a slight increase in acidity over the pH of 5.8 at the beginning of the test.

The policy followed by the college Grounds Department was to apply fertilizer only in early April. However, with athletic fields that are used in the fall, it would be desirable to apply at least one-half of the fertilizer in early September as tests have shown (1) that grass fertilized with one-half the total amount of fertilizer in April and again in early September produced better turf with regard to color, density and vigor than where all the fertilizer was applied in the spring.

Conclusions

In this study the most desirable turf for an athletic field on which fall play is very heavy was developed, not from a pure seeding of any one grass, but by a mixture of grasses. The mixture that appeared best suited was 2 pounds Chewing's fescue, 1 pound Kentucky bluegrass, 1 pound Colonial bent and 2 pounds Pacey's perennial ryegrass per 1,000 square feet.

In these tests Pacey's perennial ryegrass and redtop have not persisted while the Colonial bents germinated and produced a stand quite as rapidly and were permanent.

Under playing field conditions in the fall, due to their habits of growth and the maintenance practices, creeping forms of Colonial bent, and velvet bent when seeded alone developed inferior turf compared to the mixtures containing them and produced brown, fluffy, and matted turf especially after frost and heavy athletic traffic. Rhode Island Colonial appeared the most desirable form of bent grass. Piper velvet bent on the varsity baseball diamond maintained at ½ inch height and topdressed occasionally has been very satisfactory.

Fescues when used alone were inferior to the mixtures that contained them, and were particularly better on plats that had peat incor-

porated with the soil. Fescues used in mixtures with Kentucky bluegrass and Colonial bent improved the resultant mixture in increasing wear-resistance.

Kentucky bluegrass appeared very aggressive, and had a dark green color especially in the fall when fescues and Colonial bents usually lacked color.

The use of peat incorporated with the soil appeared advantageous as it was on the peat plats that the most satisfactory turf developed by the intermingling and close association of Kentucky bluegrass, Colonial bent and fescues.

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Response of Red Oak to Fertilization with Ammonium Sulfate

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

THE response of pin oak and American elm to ammonium sulfate has been reviewed in previous papers (1, 2). The appearance of these trees was improved with respect to foliage color. Green foliage was retained until late autumn where ammonium sulfate was used as a fertilizer. Trunk diameter or girth, also twig elongation and increment borings were used as criteria of growth but no statistically significant differences were found.

One hundred and ten red oaks planted along Tower Road were fertilized from 1936 through 1940 using ammonium sulfate at the rate of 10 ounces of fertilizer for each inch of trunk diameter taken at breast height. The fertilizer was applied either broadcast or in holes 10 to 12 inches in depth. Applications were made between April 15 and May 1. In other tests a complete fertilizer 6–8–4 was used at the same rate based on nitrogen content.

The results are stated in terms of percentage increase for the four-year period. The trees were grouped into two classes according to their girth. Those of the smaller group include trees of 4 to 10 inch girth while the larger trees range from 20 to 40 inches in girth.

TABLE I—Response of Red Oak to Fertilization Over Four Year Period

Fertilizer	Application	No. Trees	Per Cent Increase Trees 6 Inches Girth	No. Trees	Per Cent Increase Trees 20 Inches Girth
6–8–4	Broadcast	3	30.19 ±2.09	6	24.96 ±1.09
6–8–4	Below surface	6	54.92 ±4.19	6	24.64 ±0.99
None	Check	4	57.59 ±4.39	12	23.49 ±1.29
$(NH_4)_2SO_4$	Broadcast	4	69.79 ±6.12	9	26.99 ±1.36
$(NH_4)_2SO_4$	Below surface	5	59.53 ±6.43	7	23.74 ±0.72

These data agree with those reported previously for pin oak and American elm growing in clay loam soil and under lawn conditions. The usual response of the lawn under fertilized trees was noted, that is luxuriant growth of grass and green color retained late in the autumn, also early color in spring. The foliage color in the trees responded as before. Among the check trees 84 per cent took on autumnal coloration at the normal time, October 15 to November 1. Where the ammonium sulfate was applied broadcast 52 per cent turned color while only 28 per cent turned color where the fertilizer was applied below the surface of the soil. The response was more marked with the complete fertilizer when 42 per cent and zero per cent had taken on autumn color by November 1.

Response of red oak to fertilization with ammonium sulfate is similar to that found previously in pin oak and in American elm. Foliage color appears to be a more reliable index of response than does girth.

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Growth of Pin Oak Following Transplanting and Pruning

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

TWENTY-SEVEN pin oak of approximately 4 inch caliper were transplanted during the fall of 1937. The trees were dug with a ball 8 inches in diameter for each caliper inch. Plantings were made in four locations using good topsoil for backfill. No fertilizer or water was applied and the tops were not pruned following transplanting. Subsequent growth of these trees was compared with that of others of similar caliper in the original location. Girth was the only criterion of growth employed. The results are given in Table I.

TABLE I—Growth of Pin Oak Following Autumn Transplanting

Treatment	Number of Trees	Increase in Girth (Per Cent)	
		1938 and 1939	1940
Site A, clay loam	4	9.49 ±1.03	15.37 ±4.15
Site B, rubble-soil particles	12	21.48 ±1.38	10.33 ±0.74
Site C, sandy	4	17.69 ±2.11	9.79 ±1.12
Site D, sandy slope	7	30.00 ±3.37	7.02 ±1.00
Original site, clay loam	34	47.67 ±0.98	15 03 ±0.35

While no ill effects were obvious in the transplanted trees, Table I indicates greatly reduced growth as compared with check trees. This effect is particularly noticeable during the first two seasons following transplanting and, with few exceptions, holds true for the third season as well.

During April 1940 a few trees in the original planting were selected to study the influence of root pruning as compared with top pruning upon the growth of pin oak. In April four trees were trenched for transplanting. The original soil was returned and no further treatment given. Six trees were pruned by removal of the lower four or five branches reducing the leaf surface by approximately 10 per cent. When compared with the check trees root pruning reduced the growth for 1940 from 15.03 per cent to 13.57 per cent while top pruning increased the growth from 15.03 per cent in the checks to 15.81 per cent in the treated group. Neither treatment resulted in statistically significant differences.

It is rather surprising that transplanting should so reduce growth while root pruning had such a limited effect. The importance of roots penetrating vertically into the soil and possibly the influence of the season, of soil or injury to the roots during transplanting may be fundamental factors. Reduction in the top by pruning of trees had no retarding effect as had previously been evident for small trees (1).

From the above data it is evident that transplanting seriously reduces growth. This cannot be entirely accounted for by root pruning or by top pruning. Season, soil and care in handling are no doubt factors of importance.

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A Measure of Preference for Rectangular Lawn Panels

By ROBERT S. REICH, *Cornell University, Ithaca, N. Y.*

THE purpose of this experiment was to determine what rectangular lawn shapes the average individual prefers. Since landscape designs are to be used and enjoyed by the public, the landscape artist should know, if not be influenced by, the likes and dislikes of the public. Experiments have been made to determine the popular choice of plain rectangular forms of various proportions as seen perpendicular to the line of vision, but there is no record of any experiment to determine the popular choice of rectangular areas appearing in perspective as would frequently be the case when viewing rectangular forms in landscape design. Since such panels (rectangular areas) are greatly foreshortened, it would seem that due to the foreshortening the most pleasing proportions would involve lengths greater in relation to widths than when forms are not seen in perspective.

Fechner (5) in 1876, in Germany, found that 35 per cent of those viewing 10 rectangles of various proportions preferred the so-called "golden section" in which width is to length as length is to the sum of width and length; thus if the width is expressed as one, the length should be 1.6+ (ratio 1:1.6). No one rated this ratio last. Rectangles with ratios of 1:1.5 and 1:1.75, and therefore not very different from the golden section, were in second place with 20 per cent preferring each one, and less than 1 per cent placing either one last. The square with 3 per cent was slightly more popular than the narrowest rectangle (1:2.5) with 1.5 per cent. Other experiments in Europe by Witmer in 1894 (5) and by Lalo in 1908 (2) gave similar results.

Later experiments in the United States, however, have shown preference for longer, narrower rectangles. Thorndike in 1917 (3) found that the preferred rectangle had proportions of 1:1.82, second choice 1:2, and third choice 1:2.22. Weber in 1931 (4), being interested in testing the supposed superiority of the "golden section" as well as the various root rectangles,[1] experimented with the square, the root 2, 3, 4, and 5 rectangles, the "golden section," and four interpolated rectangles which served as transition forms between the root rectangles. None of the special ratios was more pleasing than its immediate neighbors, and the proportion of 1:1.87 (one of the interpolated rectangles) rated as the most pleasing. The root 3 (1:1.73) came second. Davis in 1933 (1) asked students to visualize and then draw freehand what appeared to them to be the rectangle with the most pleasing proportions. The drawings ranged from the square to 1:9.75. There were three modes, 1:2 being the most common, and closely following were 1:1.75 and 1:2.25. So much for experiments with rectangles not appearing in perspective.

PROCEDURE

In our own experiment five rectangular pieces of land equal in area but varying in proportions were enclosed by boards, 8 inches high by

[1]The width is to the length as 1 is to the square root of 2 (root 2 rectangle), or as 1 is to the square root of 3 (root 3 rectangle), etc.

1 inch thick, which were painted white inside and dark brown outside. The sizes of the plots were as follows: plot A—39 feet square (ratio 1:1); plot B—22⅔ feet wide, 68 feet deep (ratio 1:3); plot C—27¾ feet wide, 55½ feet deep (ratio 1:2); plot D—24 4/5 feet wide, 62 feet deep (ratio 1: 2½); and plot E—31⅓ feet wide, 47 feet deep (ratio 1:1½). The plots were viewed from one end only. At the far end of each was one of five identical benches. Backgrounds and environments were practically identical.

In the first study 136 observers, most of whom were in some of the various summer school classes at Cornell University, ranked the plots in the field. The judgments of the few (about 15) who had had previous art or landscape training did not vary enough from the judgments of the entire group to warrant separate consideration.

The observers were asked: (a) to rank the plots in the order of the satisfaction they afforded, (b) to give reasons for their first and fifth choices, and (c) to rank the plots according to their apparent size. The same questions were asked in studies 2 and 3 to be discussed later. The reason for part b of the questionnaire obviously was to see if the observers could help us to determine the reasons for their likes and dislikes. In none of the studies were they able to give any worthwhile answers to this question. About all that was said was that the plots which they preferred appeared to have better proportions. Part c was included because apparent size was thought to be an important factor affecting satisfaction from proportions. The results in this study and in subsequent studies showed no such relation. Many observers had difficulty in judging apparent size, and some failed to do so. In these various studies the observers exhibited a much lower power of discrimination (a smaller range in mean scores) for the apparent size of the plots than for the satisfaction derived from observing the plots.

Three sets of photographs were taken of each of the five plots, as follows: *series one* taken from 5 feet in front of each plot (most of the field observations had been from about this distance); *series two* taken 40 feet from each plot (the greatest distance needed in series 3 — for plot A); *series three* taken far enough from each plot so that its front line extended the full width of the picture.

In the second study these photographs were used, to make two slides, one showing the five photographs in series one, and one showing those in series three. From these two slides 167 students in an elementary psychology class ranked the five plots as in the previous study. The ranking and mean scores for series one agreed very closely with the results from the field study (Table I). With series three there was a shift of preference away from the shorter and towards the longer plots. This was undoubtedly the result of the foreshortening effect produced when viewing the plots from the more distant positions.

A third study was run in conjunction with the University of Connecticut's fall horticulture show. It involved the use of 15 photographs, consisting of each of the five plots in each of the three series. The inclusion of series two, in which the pictures of all plots, except plot A, were taken from a still further distance than in series three, is probably the cause of the further shift in preference to the narrow plots

TABLE I—A SUMMARY OF THE VARIOUS STUDIES TO MEASURE HUMAN PREFERENCES FOR RECTANGULAR LAWN PANELS

Study No.	Plot	No. of Observers	Choices of Plots Based Upon Mean Scores					Mean Scores Given by the Observers*				
			A	B	C	D	E	A	B	C	D	E
	Viewed at Close Distances											
1	Field observations	136	5th	4th	1st	2nd	3rd	1.01 ±0.07	1.14 ±0.08	3.03 ±0.04	2.76 ±0.07	2.05 ±0.07
2	Slide of five plots, series 1	167	5th	4th	1st	2nd	3rd	0.62 ±0.06	1.68 ±0.06	3.05 ±0.05	2.74 ±0.06	1.92 ±0.06
4	Paired comparison, six slides, series 1	68	...	4th	1st	2nd	3rd	....	0.46 ±0.06	2.10 ±0.05	1.75 ±0.06	1.52 ±0.09
5	Paired comparison, six slides, series 1, second showing	62	...	4th	1st	3rd	2nd	....	0.37 ±0.07	2.42 ±0.07	1.37 ±0.06	1.81 ±0.07
5†	Paired comparison, twenty slides, series 1	62	4th	5th	1st	3rd	2nd	1.11 ±0.10	0.82 ±0.09	3.13 ±0.07	2.04 ±0.08	2.73 ±0.08
	Viewed at Greater Distances											
2	Slide of five plots, series 3	167	5th	3rd	1st	2nd	4th	0.47 ±0.05	2.31 ±0.07	3.05 ±0.05	2.63 ±0.05	1.54 ±0.06
5	Paired comparison, twenty slides, series 3	62	5th	3rd	1st	2nd	4th	0.73 ±0.09	1.96 ±0.11	3.17 ±0.07	2.36 ±0.09	1.57 ±0.09
3	Photographs of all three series combined	100	5th	3rd	2nd	1st	4th	0.83 ±0.08	2.12 ±0.10	2.67 ±0.07	2.75 ±0.07	1.63 ±0.08

*In those studies (number 1, 2 and 3) involving the ranking method, each observer's first choice was given a score of 4, second choice a score of 3, and so on down to the fifth choice which was given a score of 0. Thus any one plot could have received a mean score of 4 only if every observer had placed that plot first, and a mean score of 0 only if every observer had placed that plot last.

Those studies (numbers 4 and 5), involving the paired-comparison technique, can be divided into two groups. In the one group plot A was omitted. Thus each of the four plots studied appeared three times. Each observer could vote in favor of any plot a maximum of three times and a minimum of zero times. The score given each plot corresponded to the number of times it was preferred by the observer. Obviously 3 was the highest possible score, and 0 the lowest possible. In the group which included plot A, each observer could vote in favor of any plot a maximum of four times. Thus the highest possible score was 4. In these studies any one plot could receive the highest possible mean score only if every observer voted for that plot every time it appeared.

Probable errors are given with the means.

†The data for the twenty slides includes the data on the six slides.

(Table I). The observers expressed considerable difficulty in having to study all 15 views before rendering judgments, and most of the observers did not even attempt to answer parts two and three of the questionnaire. Consequently, in subsequent studies, all of which were with slides, the paired-comparison technique, in which only two plots can be observed at a time, was used.

The fourth study involved six slides on each of which was a pair of plots. In this way plots B, C, D, and E in series one were presented to the students in an elementary horticulture class. While these students were interested in the general field of landscape gardening, most of them had had little or no previous art or landscape training. For each slide the observers indicated (a) which of the two plots they preferred, (b) why they preferred it, and (c) which of the two plots appeared the larger. Since in all previous studies plot A had been the least popular, it was omitted from this particular study to conserve time. The incorporation of plot A would have necessitated the use of four more slides. The results checked with studies 1 and 2 (Table I).

The fifth study was made only on the satisfaction obtained by looking at the photographed plots. One week after the fourth study had been made, the same students judged the original six slides, plus the four necessary to include A, plus a duplicate set of ten to check upon the effect of position of the plots as seen on the slides (top or bottom). At the same time a similar group of two sets of ten slides each of series three was judged.

The use of duplicate sets proved to be unnecessary. In both series one and three the average ranking was the same in the first ten as in the second ten slides, and the mean scores were practically the same. In no case was there a significant difference between the mean score for any one plot in one set and the mean score for the same plot in the other set. Thus it is concluded that placing the plots on the top or bottom of the slide results in no appreciable difference in the judgments of observers.

The fact that the six slides of series one which had been used in the fourth study were included in this more extensive part of the experiment provided a check on judgment after an interval of one week. Apparently there was a shift of preference toward the broader plots as shown by the reversal of D and E. It should be noted, however, that the difference between these plots in the fourth study had not been significant (Table I). The results of the judgments of series one also show plot A, which had been omitted from the fourth study on the assumption that it would be ranked last anyway, being preferred to B. This liking for plot A may be accounted for by the fact that while the other four plots had been studied by these observers only one week before, A was new to them.

The results of the judgments on the slides in series three checked with the same series in the second study (ranking method).

Discussion

The ranking method which was used by Thorndike (3) involves judging several objects at a time upon a certain characteristic, and then ranking them in order. Studies one through three were based on

this method. Many observers in the field had difficulty keeping the effects of all plots in mind. By the time they had seen all five, they had forgotten the first. For many observers this involved walking back and forth several times. In the third study, although no walking was involved, 15 photographs proved much more difficult to study and rank than five field plots. Apparently the second study, with all five plots on one slide, was the easiest for the observer to rank.

The paired-comparison technique, used by Weber (4) and used in the fourth and fifth studies of the experiment under consideration, actually involves an analysis of the thinking that an observer would have to undergo in making judgments by the ranking method. Thus the results should be more accurate. In this particular experiment the monotony resulting from having to see so many slides of the simple rectangular figures was a disadvantage.

The duplication of slides in the fifth study showed that the judgments of the observers were not affected by the position of the plots on the slides.

Another disadvantage with field tests is the difficulty in persuading people to go out to make the observations. Photographs and slides can be brought to them. Of course, the trouble with photographs and slides is that they fail to show as much as the observer can see in the field. It should be noted, however, that in this experiment the results by slides checked very well with the field observations. (The discrepancy in the results from the photographs has already been explained.)

Summary

Under the conditions of this experiment the most commonly preferred proportion for a rectangular lawn panel, as seen from about 5 feet away, involved a ratio of 1 to 2 (expressing width as 1). This checked fairly well with the more recent experiments with rectangular forms not appearing in perspective. From more distant positions foreshortening due to perspective became greater. This resulted in a preference for the longer plots. It is worth noting, however, that in the two most accurate of the three studies of the plots as seen from a distance, the 1 to 2 ratio continued to rank first, the 1 to 2.5 still ranked second but the 1 to 3, instead of 1 to 1.5, ranked third. In the third study the 1 to 2.5 ratio ranked ahead of the 1 to 2, but the difference was not great enough to be significant.

Further studies to verify these conclusions, as well as further analysis of landscape problems by the methods of approach used in this experiment would be desirable. From all appearances this procedure lends itself to a wide range of studies in commercial art.

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First Courses in Horticulture[1]

By R. A. Van Meter, *Massachusetts State College, Amherst, Mass.*

AT THE start of this study a survey of First Courses in Horticulture was made from college catalogues, personal correspondence, and a questionnaire sent to each land grant college. This survey made it possible to group first courses into broad classes. Since the situation is not comparable in any two states and curricula vary widely, this attempt at classification may not interpret conditions exactly in a few borderline cases, but it is believed that errors, if they do exist, are of minor importance.

Forty-two colleges are included in this study. Thirty-eight of these do have first courses required of all students in horticulture. Connecticut, Cornell, California, and Alabama do not have such courses. In many states these courses are required of all students in agriculture and often are the only courses in horticulture required of non-major students.

In half the states (19) the beginning course is given in the freshman year; in 16 states it is given in the sophomore year, and it is given in either year in Illinois, Kentucky, and Virginia. Less than half (17) of the states find their beginning courses even fairly satisfactory.

Beginning courses are taught with various ends in view, and have been grouped under four headings, as follows:

1. *Principles of horticulture as they may be applied on the general farm.* These courses usually cover fruits, vegetables, and flowers, as in Arizona, Iowa, Georgia, Maine, Nebraska, and South Dakota. Sometimes ornamental horticulture also is included, as in Washington. In Oregon, horticultural products take the place of floriculture. As a highly developed course of this type, the outline of the course at Iowa State College has been duplicated and sent to each department of horticulture in the United States.

Where farm horticulture is a major concern of the department this course seems to be satisfactory. Often it is required of all students in agriculture and it may be the only course in horticulture taken by many students from other majors. It meets the needs of these students as well, perhaps, as a single course can be expected to meet them, while for students majoring in Horticulture it serves as a preliminary survey of the field and meets the student demand for a course early in the four years that may be turned to immediate account. It is criticized for "skimming the cream" from later, more specialized courses, and several states express dissatisfaction without specific criticism.

2. *Orientation work of general background material on which later courses are built.* In this group are included Ohio, Maryland, Rhode Island, North Carolina, North Dakota, Louisiana, Oklahoma, Michi-

[1]This paper is the result of a study of beginning courses in horticulture, undertaken by the Committee on Education: R. A. Van Meter, Chairman, Massachusetts; Laurenz Greene, Indiana; C. H. Mahoney, Maryland; R. E. Marshall, Michigan; E. L. Overholser, Washington; Kenneth Post, Cornell; G. J. Stout, Pennsylvania.

gan, Missouri, Idaho, New Hampshire, and also Kansas, where the stress is placed upon agronomic principles. Interest in courses of this type is so widespread that course outlines used in Maryland, Michigan, Missouri, and Ohio have been duplicated and sent to each department of horticulture.

About half of these 13 states are not satisfied with their courses. Various objections are raised, including: (a) It is background material only and is inadequate for students who go no further in horticulture. (b) One semester is not time enough. (c) Few instructors are broad enough to teach it properly. (d) Students at this stage need a textbook and there is no available text on general horticulture that is of college grade. (One text has appeared since this criticism was made).

Much of this background material comes from sources in fundamental science, and it is difficult for the horticulturist first to supply the science and then to focus it upon horticultural material. Much of this material is taught easiest later on in specialized courses to juniors and seniors who have a background of fundamental science. However, about half the states which use this type of beginning course have adjusted it fairly well to their needs.

3. *Specialized work, usually in fruits or vegetables.* Such courses are required of all students in Minnesota, Vermont, Colorado, Delaware, Mississippi, Virginia, Kentucky, and Montana. Sometimes ornamental horticulture is included as in Illinois, South Carolina and West Virginia.

Where two or three subjects are included as in Colorado this becomes a restricted survey course; where two or three courses are offered and a choice of one required, as in Minnesota, it becomes early specialization. Early specialization is objected to by some on the ground that too few freshmen can definitely decide where they wish to specialize. It complicates the transfer problem later on. However, several of these states seem to have solved their problem quite satisfactorily.

4. *Comprehensive work in propagation.* These include Pennsylvania, Massachusetts, Delaware, Indiana, and Texas. Arkansas also follows this plan but adds landscape materials, while Florida uses propagation and pruning. At Purdue a course in propagation and a course in principles of fruit growing are required of all freshmen in Pomology, Vegetable Gardening, Horticulture, and Floriculture. The outline of the course at Pennsylvania State College has been duplicated and distributed as that of a well developed course in propagation.

These states mostly report at least fair satisfaction with these courses. It is difficult, however, to teach propagation so thoroughly to freshmen that it does not need repetition or at least careful review later in more specialized courses. On the other hand, propagation is one subject that is common to most of horticulture, requires manipulation and study of horticultural material, and involves related sciences in such a way as to give it considerable value as motivation for science courses.

Among land-grant colleges that do not have any one required first course covering horticulture in a broad way, Cornell has a semester of floriculture and ornamental horticulture followed by a semester of

landscape principles. This is open to freshmen. General courses are offered in pomology and vegetable crops also. These are not open to freshmen but are taken in the sophomore or junior year.

In California the work usually covered by pomology is separated into four distinct divisions: (a) Deciduous fruits; (b) Subtropical Horticulture; (c) Viticulture; and (d) Fruit Products. A general course in fruit growing is prerequisite to further work in any of these divisions.

Connecticut has no general courses in horticulture. Alabama has no general course in horticulture but has four courses required of most students in agriculture. They are orchard management, vegetable gardening, landscape gardening, and forestry.

Conditions vary so widely across the country that it cannot be said that any one type of beginning course is best. Nor is it surprising tha so much dissatisfaction is expressed for all of them.

It is difficult to present basic horticultural material of college grad before students have been exposed to fundamental science — at leas in botany. It would be easiest to teach a beginning course in the junio year, but too many students who enter college fired with enthusiasi for horticulture feel thwarted and lose the fine edge of their intere: when faced with two years of preparatory work, or even find ne interests and never reach us at all. So beginning courses in horticultu have been pushed back as far as the first semester of the freshman yea

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